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The Development of Children's Expertise in Tennis: Knowledge Structure and Sport Performance.

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The Development of Children's Expertise in Tennis: Knowledge Structure and Sport Performance

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by

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Foreword

This mauscript is written in the format of the American Psychological Association. The body of the paper is presented in the format of submission for publication to scholarly journals. Additional information concerning measurement instruments and procedures, statistical procedures, tables, and studies reviewed for the study are presented in the appendices.

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Abstract

This research examined children's development of knowledge structure and sport performance in tennis. A knowledge test was designed to measure declarative knowledge and a serve and groundstroke skill test were developed to measure skill. An observational instrument was designed to record the components of performance for the serve (decision and execution) and game play following the serve (control, decision and execution). Phase 1 compared expert and novice tennis players within two age levels, 10-11 years-old and 12-13 years-old, on the individual components of tennis performance and on measures of tennis knowledge, serve skill, and groundstroke skill. Experts regardless of age performed better than novices on tennis skill and knowledge; experts' decisions and actions were better during tennis game performance. Declarative knowledge was related to the development of procedural knowledge, whereas serve and groundstroke skill were related to the motor execution components of performance. In phase 2 verbal reports were used to assess the bases of decisions during game play. Point (during game play) and situation (after game play) interviews were used. The results were based on two measures of knowledge structure, i.e., what was stored (the total number, the variety, and the characteristics of concepts within condition, action, and goal concepts), and how it was stored (the number of connections between

concepts and the linkages across and within condition, action and goal concepts). Experts as compared to novices, focused on higher level concepts, had more interconnections among these concepts, and had available a wider variety of condition and action concepts that were important to the goal structure of the game. Overall, the expert's greater decision-making ability during game play was directly related to their knowledge structure.

Introduction

Developmentalists in verbal and motor behavior have begun to link differences in performance to changes in children's knowledge of specific content. Prior to this, cognitive and motor skill research demonstrated age-related performance differences; however, recent investigations directed towards expertise levels indicate age-related differences are not as important a variable as expertise. Further, the experts' skilled performance is predicted to be influenced by their knowledge structure allowing them more effective and efficient use of their knowledge during performance.

Contrasting high- and low-knowledge children, Gobbo and Chi (1986) found the degree of structure in the domain of dinosaur knowledge crucial in predicting the success of performance on memory and related tasks. Verbal report analysis of the knowledgeable children's consistent reasoning in a sorting task interacted with reasoning in their knowledge domain (i.e., sorting based on abstract features). Opposite this, low knowledge children were literal in their reasoning and inconsistent in their sorting. Within a sport, Allard and Burnett (1985) found similar contrasts of basketball expert and novice adult players in a picture sorting task consisting of scenes of game play. Verbal report analysis again revealed experts sorted consistently on abstract principles (e.g., zones, offenses), whereas novices categorized on the literal features of the pictures (e.g., two people playing, one person playing).

In a study similar to the present one, French and Thomas (1987) examined the relation of knowledge base to sport performance according ratings. They investigated the relation of the amount of basketball knowledge and the ability to make appropriate decisions during game play together with the amount of sport skill and the ability to execute sport skills effectively during game play. Using an observational instrument, they coded the cognitive and motor skill components of actual game performance. French and Thomas found the cognitive decision-making component, rather than the motor skill components (i.e., control and execution), to be the maximum discriminator of expert and novice children regardless of age during offensive basketball play. They also inferred from a multiple-choice knowledge test (assessing both declarative and procedural knowledge) and an open-ended situation interview that experts recognized relevant information, recalled larger amounts of better organized information, and understood the importance of actions of the opposing team. That is, the experts who performed well, speculate French and Thomas (1987) and Thomas, French, and Humphries (1986), did so because the experts (regardless of age) had sufficient basketball knowledge (i.e., knowledge about the game, its goals and actions, knowledge of monitoring skills, and knowledge of actions within the context of the sport).

Examinations of text processing of high-knowledge baseball fans (Chiesi, Spilich, & Voss, 1979; Spilich, Vesonder, Chiesi, & Voss, 1979) and verbal reports gathered during phases of actual competetion of an expert badminton player (Housner, 1981) revealed similarities in the representation of sport-specific knowledge. These studies indicated that experts have more highly developed sport-specific knowledge structures and cognitive processes to operate on this knowledge structure (e.g., the chunking of crucial strategic events, attention toward certain environmental cues) when contrasted with less-knowledgeable fans or novice players.

An adequate theory of the role cognition plays in sport performance must explain how relevant knowledge facilitates a players cognitive decision-making ability during game play. To date research is limited in terms of how (or in what ways) sport-specific knowledge influences decision-making skill during actual game play. Based on past research (e.g., Chiesi et al., 1979; French & Thomas, 1986; Gobbo & Chi, 1986; Housner, 1981; Spilich et al., 1979) and present speculations (see, Thomas et al., 1986; Thomas, French, Thomas, Gallagher, in press) differences between experts and novices should occur in terms of what experts know about response selection and what experts do with what they know in order to select an appropriate response in the context of a game situation.

Specifically, the goal structure of a problem or a sport situation may affect the quality of decisions(s) made in the context of a game situation. The knowledge structure of sport, so far, has been operationally defined to include knowledge of the games goal structure (e.g., means by which a game is won, usually hiearchially organized) combined with knowledge of related game actions in terms of the games goal structure (i.e., knowledge of relations of actions to goals). This may be conceptualized as declarative knowledge, a propositional network of facts inherent in the sport. Sport knowledge may also include patterns or rules for generating patterns of actions to produce goal related changes in the context of a game situation (Chiesi et al., 1979; Spilich et al., 1979). These rules or patterns (procedural knowledge) and factual knowledge (declarative knowledge) within a certain domain adhere to frameworks involved in developmental (e.g., Chi & Ceci, 1987; Chi & Rees, 1983) and computer simulated (e.g., Anderson, 1981, 1983) learning. Procedural knowledge is organized around conditions (the circumstances under which the production can apply) and actions (what should be done when the production applies) which are influenced by the current goals and context (stimuli from the environment). Chi and Ceci (1987) and Anderson (1983) also speculate that declarative knowledge must be accumulated prior to the development of procedural knowledge.

Within a sport-specific domain, Thomas et al. (1986) and Thomas et al. (in press) speculate that the role knowledge base development plays in sport performance is due to more effective and efficient response selection (e.g., in less time and with less information within the context of a game situation). Experts with greater decision making ability are expected to structure knowledge at a more sophisicated (higher) level consisting of highly structured offensive and defensive sport concepts. Experts are expected to exhibit a greater number of concepts, more interconnections among concepts, and more rules concerning how to perform in response to a specific situation (e.g., Adelson, 1984; Chase & Simon, 1973 a b; Chi, 1978; Chi & Koeske, 1983; Chi, Feltovich, & Glaser, 1981; Chiesi et al., 1979; Gobbo & Chi, 1986; Murphy & Wright, 1984; Spilich et al., 1979). Overall, experts are predicted to have available a wider variety and/or more alternative productions (i.e., rules) that are important to the goal structure.

Another interplay of knowledge and its sport specific processes during actual game play is speculated to be the result of the skilled performers' execution ability. This allows more attention or quick access to their knowledge structure which results in better anticipation and prediction (e.g., Keele, 1982; Thomas et al., in press). The redundancy of fast action skill in rapidly changing environments is stored in the expert's knowledge. Novices, however, may not have acquired or have stored the skill allowing them the opportunity to quickly access this knowledge structure. Also, novices may apply skill execution as an overriding goal concept (as opposed to a strategic concept) in their knowledge structure due to their lack of sport skill or action automation.

As reviewed, a useful way to assess the role of sport-specific knowledge in sport performance is a research paradigm examining expert and novice differences. This study contrasts expert and novice child tennis players within two age groups in terms of their tennis knowledge structure (i.e., organization) and the ability to apply this tennis knowledge to make an appropriate response in the context of a game situation. Based on previous results, experts regardless of age are expected to exhibit more tennis knowledge and skill. The most dramatic expert/novice differences are predicted to occur in terms of the experts' greater decision-making ability (i.e., response selection) during game play which reflects their more sophisticated knowledge structure. Overall, expertise is expected to override all age and age by expertise effects as knowledge structure of a specific domain is predicted to influence decision-making ability (i.e., reasoning) during performance. Specifically, the following questions were addressed:

1. Is the quality of decision-making ability related to skilled performance?

2. Are there differences in the type and degree of knowledge structure according to the quality of decision-making ability?

3. Are there differences in the use of this knowledge relative to decision-making ability during actual game play?

Research in this area may contribute to understanding the knowledge-base/performance relation as expertise is achieved. The examination of sport-specific knowledge and how this knowledge influences cognitive decision-making ability may be useful for practitioners in terms of training (e.g., teaching certain sport-specific if-then-do rules) or diagnosis of children's sport performance (e.g., identifying a weak procedure). Also, if experts are found to structure knowledge in a specific manner, then researchers and eventually practitioners may develop ways to explicitly convey this to novices to increse their ability in sport performance. The investigation of the knowledge base and performance interaction within a sport domain may contribute to understanding the developmental issues in cognition. That is, the task used to assess performance differences is not arbitrary but inherent in the knowledge base under investigation. Also the child participants are highly motivated and are assessed in conditions similar to their natural environment during performance.

Phase 1

The relation of the quality of decision-making ability to skilled performance is addressed in Phase 1. Examining the role of cognition in a sport setting (singles tennis) should first entail an examination of sport performance. Sport performance involves three components: 1) knowledge about the game, 2) the ability to execute the necessary sport skills, and 3) the interaction of knowledge and skill during game situations (Thomas et al., 1986). The first step was to examine the first two components, knowledge and skill. The relation of tennis knowledge, serving skill, and groundstroke skill was examined within two age groups (10-11 and 12-13 years) of expert and novice child tennis players. The level of expertise was predicted to override all age and age x expertise effects. Skill was expected to produce the most dramatic expert/novice differences as knowledge about the game (i.e., declarative knowledge) is predicted to develop prior to decision making ability (i.e., procedural knowledge) during game play. Overall, both cognitive and motor skills are prdicted to contribute to the development of skilled performance.

Next, to examine the interaction of knowledge and skill during game play, these same children were observed during singles tennis play and the relation of the components of performance (motor and cognitive) was compared as a function of age and expertise. During game play the knowledge component of performance (cognitive decision-making ability) was expected to maximally discriminate between expert and novice tennis players regardless of age. Finally, how tennis knowledge, serve skill, and groundstroke skill were related to the components of performance was examined. A significant relation was predicted between the sets of variables as performance tests (knowledge, serve, and groundstroke) are expected to be predictors of decision and execution ability during game play.

Method

Subjects

Male participants from a summer tennis camp program and recreation junior tennis program served as subjects. Experts were independently defined as advanced tennis players with tournament experience and high levels of tennis skill. Novices were also independently defined as beginner players without tournament experience and minimal levels of tennis skill. Before attending the camps, players were asked to identify their level of experience: beginner, advanced, or tournament player on the application form. Each player's expertise level was then verified by experts (the camp director and 3 head instructors participating in the camps and the head instructor participating in the recreation camp). Skill level verification periods were conducted the first day of both programs lasting a period of 3-4 hours in which all camp participants were observed during drill sessions and game play. Following this period, the experimenter (certified in tennis instruction) together with the instructors classified male players as novices and experts according to the characteristics defined earlier; the players were selected from the beginner groups and advanced/tournament groups. Finally, each player selected from the group was administered an experience questionnaire (for characteristics see Table 1). The questionnaire was designed to assess each individuals tennis experience.

Insert Table 1 about here

A total of 40 male players was selected as expert or novice according to their previous tournament experience and skill level. Two age groups were selected, 10-11 years and 12-13 years. These ages were selected as most junior tournaments are classified according to this age span (e.g., a 2 year period- 10, 12, 14, 16, 18 year olds). Ten players formed each of the four groups (N = 40): expert 10-11 year-olds, M = 132.8 months, S = 4.6 months; novice 10-11 year-olds, M = 132.6 months S

= 8.5 months; expert 12-13 year-olds, M = 157.6 months S = 6.6 months,and novice 12-13 year-olds, M = 154.8 months, S = 8.0 months

Instrumentation

Several months prior to this study, an instrument was developed to examine tennis skill, tennis knowledge, and actual game performance of expert and novice male tennis players, ages 8-13 years.

Reliability and validity testing was conducted with 8-13 year old males from a local junior tennis program and the first two sessions of a summer tennis camp.

Tennis Knowledge Test. A 50-item multiple choice test to examine tennis knowledge (factual or declarative) was judged valid in content by 3 certified instructors and an elementary educator in terms of language, terminology, balance, and coverage of factual tennis knowledge (e.g., rules, player positions, stroke production, and scoring). The written test was administered to expert and novice male tennis players ages 8-13. The results indicated the knowledge test was a reliable measure of tennis knowledge, KR-20=.81. The median index of difficulty was .50. The mean of the index of discrimination was .31. The test was also shown to discriminate between expert and novice tennis players regardless of age. The results indicated that the knowledge test was a reliable and valid measure of tennis knowledge for boys ages 8-13 years-old (for more details of the development of this test see Appendix- Knowledge Test).

Skill Tests. The reliability and validity of the skill tests was established by a test-retest procedure and expert judgment. For skill evaluation, a groundstroke and serve skill test was constructed by modifying a variety of accepted skill tests (Avery, Richardson, &

Jackson, 1979; DiGennaro, 1969; Gruetter & Davis, 1985; Purcell, 1981). The skill tests were deemed valid by 4 tennis experts. The skill tests were administered twice to male expert and novice players ranging from 8-13 years of age. Groundstroke skill was measured by having players position themselves at a point behind the center service stripe on the baseline. The tester, the experimenter, delivered a total of 24 balls (judged good by the experimenter, an expert) to each player who attempted to stroke 10 forehand and 10 backhand groundstokes. The trials consisted of 1 practice followed by 5 scored cross court and 1 practice followed by 5 scored down the line for each groundstroke. Scoring of the forehand and backhand groundstroke consisted of marked number zones (designated 3, 2, and 1) with the higher score nearer the baseline. The total possible points for groundstrokes was 60 points. Serve skill was measured using procedures similar to the groundstroke skill test in which the serve was scored on the bases of the target area hit. The subject served from the service position and served into two separate target areas (forehand and backhand service zones) for both the right and left service court. Intraclass reliability estimates for the serve and groundstroke skill tests were .91 and .72 for the younger age group, and .87 and .88 for the older age group. Experts and novices differed significantly on the groundstroke and serve skill tests. (See Appendix- Tennis Skill Tests)

Game Skills. To investigate game skills, players were filmed during actual game play. An observational instrument was designed to record the components of performance (control, decision, and execution) of children during singles tennis play. The serve during game play was coded for decision and execution while game play following the serve was coded for control, decision, and execution. The quality of decisions during the serve was coded as a 1 if the player made a strong strategic decision in the context of a given situation. A 0 was coded as a weak decision if the player made a poor strategic decision in the context of a given situation. Execution of the decision for the serve was coded in terms of the type of error (out or netted serve) and whether or not the execution was forcing (i.e., usually placing pressure on the opponent due to placement speed, spin, or depth) or a successful serve without speed spin, depth, or placement. All players were able to contact the ball in order to make a decision, therefore a control category for the serve was not necessary. Game play following the serve was coded as to whether or not the player gained and maintained control of the tennis ball. Once contact (control) was made the decision regarding the action to perform (offensive or defensive) was coded as a 1 for an appropriate decision (a strong decision) and a 0 for an inappropriate descision (a weak decision). The execution of an action was coded as to whether or not the palyer executed the decision successfully. Errors were coded as an unsuccessful execution. Decision rules were developed for each category by agreement among 3 experts (see Appendix Game Skills).

The total number of successful controls of the tennis ball was divided by the number of opportunities to respond. The total number of strong decisions was divided by the number of opportunities to respond in the decision category. Also, the total number of forceful executions was divided by the number of opportunities to respond. As a result, percentages for successful control, strong decision, and forcefull executions were determined for each individual. The types of errors and unforceful executions were also recorded.

Using four experts and four novices 10-13 years of age, interrater and intrarater reliability was established among expert judges for all categories of the coding instrument and ranged from .82 to 1.00 (see Appendix- Game Skills).

<u>Testing</u>

The measurement instruments described previously were administered to all subjects at each camp session: the tennis knowledge test, the serve skill test, the groundstroke skill test, and the observational instrument. The paper-and-pencil multiple choice knowledge test was administered prior to the other tests the first day of each camp session or recreation program. All subjects were administered the test in meeting rooms, available at both programs. In all settings, the test and scoresheet were explained prior to testing. Each subject read and answered the questions. There was no time limit. The experimenter was available at all times to answer any questions while the test was administered. The percentage of correct scores was used in the analyses. Skill testing was administered by the experimenter (an expert) on a regulation tennis court to each individual in small groups of 3 to 4 subjects. Total scores for the 20 groundstroke trials and 20 serve trials were used in the analyses. The groundstroke skill test was administered prior to the serve skill test with ample practice and rest periods between each test.

Game play was videotaped by the experimenter for all subjects. The filming was done from off court and there were no spectators. Subjects were familiarized with filming prior to the actual taping used for the experiment. All games were videotaped using a Panasonic video recorder (model NV-8200) and a Panasonic color video camera (model WV-39900B).

Sound was also recorded. All players were told they were going to play a set of tennis although filming ended after 6 games were completed. Players went through their traditional match warm-up until both players agreed they were ready. The only exception to regulation play was elimination of changing sides after every first and odd game (for recording purposes). Regular scoring was used. For analysis, coding was done without the coders' knowledge of the players expertise level or age.

Results and Discussion

Knowledge, Serve, and Groundstroke Skill

In order to determine which factors discriminate experts from novices, a 2 x 2 (Age x Expertise) MANOVA was performed on the scores of the knowledge test and both skill tests. The results of the MANOVA indicated significant effects for expertise, $F(1,34) = 31.79$, $p < .01$, with no significant age, $F(3,34) = 0.21$, $p > .05$, or interaction, $F(3,34) = 0.46$, $p > .05$, effects. The main effect of expertise was followed up by a stepwise discriminant analysis with alpha for entering variables set at .05. On univariate tests all variables significantly discriminated between experts and novices. The groundstroke test accounted for 61% of the variance, followed by the serve test, 58% of the variance, and the knowledge test, 34% of the variance. Also, the correlation ($N = 40$) of the variables was .76 between the groundstroke and the serve test, .61 between the knowledge test and groundstroke test, and .43 between the knowledge test and serve test. The discriminant analysis for expertise revealed the groundstroke test was stepped in first, $F(1,38) = 60.96$, $p < .01$, followed by the serve test, $F(2,37) = 7.81$, $p < .01$. The knowledge test was not significant, $F(3,36)$

= 2.57, p >.05, after the two skill variables were entered. The combination of the two skill tests accounted for 79% of the variance. Overall, experts were found to possess more tennis knowledge and skill regardless of age. The means and standard deviations for the knowledge, groundstroke, and serve tests for experts and novices are presented in table 2. Although the groundstroke and serve test were the major factors discriminating expertise, the experts' knowledge scores (M = 65.7, S = 10.9) were significantly better than the novices' (M = 47.4, S = 15.2), $F(1,36)$ = 68.72, p <.01.

Insert Table 2 about here

As predicted experts performed better than novices on all performance tests regardless of age. The characteristics of expertise includes a higher level of both cognitive and motor skill as experts exhibited more declarative tennis knowledge (i.e., factual information about the rules, scoring, stroke production, etc, in the game of singles tennis) and demonstrated higher levels of tennis skill regardless of age. Skill produced the most dramatic expert/novice differences followed by knowledge (i.e., declarative). These results adhere to the predictions that declarative knowledge develops prior to procedural knowledge (e.g., Chi & Ceci, 1987). These findings were inconsistent with the findings of French and Thomas (1987); however, expertise levels were formulated on the basis of coaches ratings where as expertise levels in this study were formulated on the basis of skill. Also, Thomas and French (1987) noted their knowledge test assessed more procedural rather than declarative knowledge which may explain why they found more dramatic expert/novice knowledge test differences.

Components of Game Play

To determine that cognition plays a role in the game of tennis, the relation between the components of performance and age and expertise were examined. Two separate 2 x 2 (Age x Expertise) MANOVAs were performed. The component categories of the percentage of correct (strong strategic) decisions and the percentage of successful (successful and forcing) executions were used as dependent variables to examine service play. To examine game play following the serve, the component categories of the percentage of successful controls, correct decisions (strong strategic), and successful executions (successful and forcing) were used as dependent variables examining game play following the serve.

The results of the MANOVA for service play indicated significant effects for expertise, $F(2,35) = 39.34$, $p < .01$, with no significant age, $F(2,35) = 1.42$, $p > .05$, or interaction, $F(2,35) = 0.76$, $p > .05$, effects. The main effect of expertise was followed up by a stepwise discriminant analysis ($p = .05$). In univariate tests both variables significantly discriminated between experts and novices. The decision component accounted for 63% of the variance, followed by the execution component accounting for 52% of the variance. Also, the correlation ($N = 40$) between the variables was .74. The analysis for expertise revealed the decision component was stepped in first, $F(1,38) = 65.82$, $p < .01$, followed by the execution component, $F(2,37) = 4.38$, $p < .05$. The combination of both components accounted for 74% of the variance. Overall, decision making ability was the primary factor discriminating service play regardless of age as child experts (M = 89% correct, S = 11%) made better decisions than did novices (M = 41% correct, S = 24%). Also, child experts were significantly more forcing (M = 51%, S = 21%) in terms of successful service performance compared to novices (M = 15%, S = 14%).

The results of the MANOVA for game play indicated significant effects for age, $F(3,34)= 5.16$, $p < .01$, and expertise, $F(3,34) = 26.53$, $p <.01$, with no interaction, $F(2,35) = 0.76$, $p >.05$, effects. The main effect of age and expertise were followed up by a stepwise discriminant analysis ($p =.05$). In the discriminant analysis for age, no variables were entered even though the linear composite was significant. In the univariate analysis for expertise the decision component accounted for 69% of the variance. Also, the correlation (N = 40) of the variables were .76 between decisions and execution, .13 between decisions and control, and .44 control and execution. The discriminant analysis for expertise revealed the decision component was stepped in first, $F(1,38) = 83.74$, $p <.01$. Control and execution were not entered. Overall, decision making ability was the primary factor discriminating game play regardless of age as child experts (M= 84% correct, S = 15%) made better decisions than did novices (M= 41% correct, S = 16%). Child experts (M = 85%, S = 29%) were similar in terms of control compared to novices (M = 82%, S = 15%). Following a trend similar to the performance component of decision, the component of execution exhibited experts (M = 52% successful and forcing, S = 14%) had higher percentages of succesful executions than novices (M = 25% successful and forcing, S = 17%). During game play, the decision making ability (procedural knowledge) was greater for experts than novices regardless of age. As noted, both cognition and skill were significant discriminators of expert/novice differences.

Knowledge, Skills, and Game Performance

A canonical correlation was performed to examine the variables of knowledge and skill and the variables of the serve components of performance (decision and execution). The analysis revealed one significant function. The canonical correlation for serve was .70, $F(4, 72) = 7.60$, $p < .01$. The canonical correlation to examine the variables of knowledge and skill and the variables of the game play components of performance (control, decision, and execution) also revealed one significant function. The canonical correlation for game play was .79, $F(6, 70) = 7.58$, $p < .01$. The standardized canonical coefficents for each significant function for serve and game play are presented in Table 3. The results of the canonical correlations suggest for the serve play both knowledge and skill have an important relation to decision about where and how to serve, but not to the execution of the serve. However, during game play, knowledge and groundstrokes are significantly related to both decisions and execution.

Insert Table 3 about here

To examine the ability of the tests (knowledge, serve, and groundstroke) to predict each component of performance during the serve and game play, multiple regressions were conducted. Serve skill and tennis knowledge were used to predict the decision and execution components of performance during serve play. The regressions exhibited a significant relation for both measures: decision, $F(2,37) = 17.64$, $p < .01$, $R2 = 48\%$, and execution, $F(2,37) = 7.88$, $p < .01$, $R2 = 30\%$. The standardized regression coefficients, partial correlations, and semipartial correlations for each component of performance and the tests are presented in Table 4. The standardized regression coefficient demonstrated serve skill as the strongest predictor of decision-making ability during service play; also, the serve test had the largest standardized regression coefficient for execution as expected. However, when the effects of the service test were partialed out, the relation of the knowledge test with decision making increased. The results may be due, in part, to the knowledge test being predominantly a measure of factual (declarative) knowledge which is predicted to develop first in novice players. Also, the serve skill test was a measure of the ability to place the ball deep and in the corners, a necessary skill required for a forcefull service execution.

When the groundstrokes and knowledge tests were used to predict game play, significant effects were found for decision, $F(2, 37) = 26.02$, $p < .01$, $R2 = 59\%$, and execution, $F(2, 37) = 19.18$, $p < .01$, $R2 = 52\%$, but not for control, $F(2, 37) = 0.87$, $p > .05$. The standardized regression coefficients, partial, and semipartial correlations for decison and execution components of performance are presented in Table 5. Again, the skill test (groundstroke) had the largest regression coefficient for decision and execution. When the groundstroke test effects are partialed out, the knowledge test increases in its relation with decision making ability. The groundstroke skill test was based on the ability to direct and place the ball deep, a necessary skill required for forceful executions during game play. Overall, those making better decisions during game play had a greater ability to direct the ball and made more forcing decisions.

Insert Tables 4 and 5 about here

Overall, these results suggest declarative and procedural knowledge as well as motor skill develop with expertise. Experts regardless of age performed better than novices on instruments designed to assess tennis skill and declarative tennis knowledge and instruments designed to assess decision and execution (procedures and actions) during actual tennis game performance. The development of declarative knowledge is related to the development of procedural knowledge as evidenced. Serve and groundstroke skill are related to the motor execution components of performance. Also, all children had an adequate level of skill necessary to get to the ball as the motor component of control was not a discriminator in age or expertise levels (most subjects gained control on most occassions). Although declarative knowledge as assessed by the knowledge test discriminated in terms of expertise, it did not produce as dramatic results as procedural knowledge (decision-making ability) during game play. This adheres to the predictions that declarative knowledge develops first followed by procedural knowledge (Anderson, 1983; Chi & Ceci, 1987). This trend is evident in the results which suggest that novices are developing a base of factual tennis knowledge (although less than experts) but in game situations novices lack decision making ability (i.e., procedural knowledge) when contrasted with experts. The next step in this investigation was to examine the development of procedural knowledge as decision-making abiltiy during game play is predicted to be related to differences in knowledge structure.

Phase 2

Phase 1 examined the role that cognitive decision making played in tennis performance. As predicted in Phase 1, tennis experts, regardless of age, made better decisions in the context of a game situation. Phase 2 examined how tennis knowledge facilitated the expert tennis players' cognitive decision-making ability during game play. Specifically, the knowledge structure of a problem or a sport situation may affect the quality of decisions made in the context of a game situation. Overall, differences were investigated, first, in terms of an individual's current status of tennis knowledge (i.e., its structure) and second, how this knowledge was applied during actual game play. Better decisions in the context of a game situation were predicted to result from the structure of the expert players' tennis knowledge (i.e., a more developed production system).

The knowledge structure of sport, so far, has been operationally defined to include knowledge of the game's goal structure (e.g., means by which a game is won, usually hiearchially organized) combined with knowledge of related game actions in terms of the games goal strucure (i.e., knowledge of relation of actions to goals). Knowledge structure also includes patterns or rules for generating patterns of actions to produce goal related changes in the context of a game situation (Chiesi et al., 1979; Spilich et al., 1979).

Experts with greater decision-making ability are expected to organize knowledge at a more abstract level consisting of highly structured offensive and defensive strategic concepts. These strategic concepts are conditions that specify when to apply the action or patterns of actions to achieve the goal. As a result, experts are expected to exhibit a greater number of concepts, more interconnections among concepts, and more and/or alternative rules concerning how to perform action(s) in reponse to a specific situation (Chase & Simon, 1973; Chi, 1978; Chi & Koeske, 1983; Chiesi et al., 1979; Gobbo & Chi, 1986; Murphy & Wright, 1984; Spilich et al., 1979).

The interplay of knowledge and skill in sport performance may not only require production rules used to model mental operations or processes, but also production rules used to model physical actions (Chi d& Rees, 1983; French & Thomas, 1987). These generalized pairings of a condition and action side may reflect increased interactions of sport specific cognitive and motor skills with the development of expertise. As a result, due to the nature of the domain of sport, productions may not only refer to the decisions concerning the appropriate action in the context of a game situation ("if - then") but also, the ability to execute the complex sport skill ("do"). The development of expertise may reflect differences in the players' ability to select the appropriate action (condition-action side) and the ability to execute what they have planned to do (execution of the action). Experts with a high level of skill and knowledge were expected to exhibit more agreements in terms of what they intended to do (action selected) and their ability or skill to execute their intention (action).

For purposes of this research the knowledge structure of tennis includes: (a) executive or higher order goal concepts embedded in all actions in the specific sport (the game of singles tennis) which is usually hierarchically organized reflecting the games goal structure, (b) condition concepts reflecting situations (e.g., "if") that specify when to apply the action or pattern of actions to achieve the goal, and finally, (c) action concepts reflecting the action sides (patterns or rules for generating patterns) of the production system (e.g., "then") to produce goal related changes in the context of a game situation. Actions may reflect decisions concerning appropriate actions in the context of a game situation and/or the motor skill necessary to execute the appropriate action. As a result, condition concepts and action concepts combined may reflect the "if-then-do" production systems stored in sport specific knowledge domains. That is, if an opponent has a weak backhand (if), I will stroke the forehand deep to his backhand to force a weak return (then), and I must effectively adjust the parameters of my forehand groundstroke to perform this skill reflecting a forceful (e.g., a deep groundstroke with topspin) execution (do).

First knowledge structure (i.e., individual's current status of tennis knowledge) was determined. Second, how this knowledge was applied during actual game play was examined, as better decisions in the context of a game situation were predicted to be the result of the structure of the expert players tennis knowledge.

Method

Subjects

The male players (*N*=40) who participated in Phase 1--10-11 year-old expert tennis players (*n*=10), 10-11 year-old novices (*n*=10), 12-13 year old expert tennis players (*n*=10), and 12-13 year old novices (*n*=10)--served as subjects.

Instrumentation

Verbal reports were used to assess the bases of decisions during game play. Two types of interviews were employed: a situation interview to assess current status of tennis knowledge and a point interview to assess how this knowledge was employed during game play. Extensive pilot work was conducted with tennis players of varying age and expertise participating in the local junior program mentioned earlier. Modifications were made to ensure obtaining verbal reports during the test conditions were as condusive as possible to actual game play.

Situation Interview. How experts approached the problem solving situations during game play was examined by a situation interview. The situation interview consisted of three categories of open-ended questions. The questions examined what players thought about in service, backcourt, and net game situations. They were as follows:

1. What are some of the things you think about before:

   a. you serve?

   b. your first serve?

   c. your second serve?

2. What are some of the things you think about when you are behind the baseline and:

   a. your opponent is behind the baseline?

   b. your opponent is at the net?

3. What are some of the things you think about when your opponent hits a short ball and you run into the service court area to hit it?

While each question was in view and read aloud by the experimenter, a diagram of the situation occuring on the tennis court was provided. The subjects were required to respond verbally to each question. While responding, question probes were used to clarify statements. To elicit further details relative to responses, or to elicit more responses, subjects were asked, "anything else?" after each response. Only, when the subject stated he had no more responses and the experimenter prompted again, was the next question asked. There was no time constraint on the session or each question. The situation interview was administered, following all other testing, by the experimenter to each subject individually. The responses of each subject were recorded on cassett tape for coding purposes.

Point Interview. The point by point interview was designed to assess how knowledge was applied during actual game play. Subjects were instructed to answer "what were you thinking about while you were playing that point?" between points during actual game play. Considerable pilot work was done to ensure that subjects were questioned as quickly as possible, without cueing the appropriate response, and as naturally as possible (e.g., a pause between points occurs in the game of tennis). Prior to playing, subjects were instructed to answer the question upon completion of the point. The question was on a sheet of typing paper in large print. This was taped to the ground in front of each of the microphones which were located directly behind the center mark of the tennis court as close to the fence as possible on each side of the tennis court. All subjects were instructed to respond as soon as the point was over. They were given no time constraint on their response. An exception to game play was that players were not allowed to change ends of the court due to recording techniques. The point interview was administered to all subjects during game play with each player (two per singles match) responding following each point during 4 games of a tennis set. The point interview was administered (two subjects at a time) during the videotaping of game play in Phase 1. Both players were instructed separately (at the end of his respective court) prior to filming. The responses of both subjects were gathered upon the subjects arrival in the microphone area (i.e., in most cases, simultaneously) at each end their respective court between each point. Responses were recorded on cassett and VHS tapes. Pilot work indicated performance reliability for decision and execution was .99 and above in all analyses for the serve and game play (See Appendix Interviews).

Coding. An instrument was designed to examine the knowledge structure of the point and situation interview. Responses were examined in terms of: what information was stored and, how this information was structured. What information is stored was measured by the total number of concepts, the total number of different concepts, and the quality of each concept. The structure of the information was measured in terms of the frequency of connections between concepts (i.e., any word that connects concepts) and the units (linkage) of concepts (e.g., a goal and an action linked together in one response).

The entire situation interview and point interview (i.e., the first 4 points of each of the four games coded in Phase 1) were coded similarly. Production protocols were transcribed verbatim and classified into one of the three major concept categories: condition concept, action concept, or goal concept (see Table 6 for classification rules). The structure of knowledge was examined for cohesion and integration. To examine integration of the knowledge concepts, the number of coded responses for each category were obtained for each individual to examine statistically quantitative differences in knowledge structure. The frequency of the total number of concepts and the use of different concepts within each category were determined for each individual (see Table 7 for examples). The quality or level of sophistication of each concept within categories were also assessed. Each individual's concepts within categories were coded in terms of the quality or characteristic of the concept (see Table 8 for quality coding rules).

Insert Tables 6, 7, and 8 about here

Interrater reliabilty of the situation interview and the point interview was determined by 2 experts classifying responses of 10 of the 40 subjects (5 randomly selected subjects each for the situation and point interviews). The coding instrument was considered reliable for all categories as interrater reliability ranged from .93 to 1.00 while intrarater reliability was 1.00 for all categories. The remaining protocols were scored by one individual. For more details, see Appendix-Point and Situation Interviews.

Results and Discussion

Situation Interview

Total and Variety of Concepts. To examine how tennis knowledge was structured the total number of responses across all situations were coded for each category of knowledge. The categories for Total Concepts (condition concept, action concept, and goal concept) were analyzed in a 2 x 2 (Age x Expertise) MANOVA for the situation interview. The results of the MANOVA indicated a significant effect for expertise, $F(3,34) = 4.85$, $p < .01$, with no significant age $F(3,34) = 1.81$, $p > .05$, or interaction, $F(3,34) = 0.43$, $p > .05$, effects. The main effect of expertise was followed up by a stepwise discriminant analysis ($p = .05$). Only the total condition concepts discriminated between experts and novices, $F(1,38) = 14.67$, $p < .01$, although experts had more action but fewer goal concepts than novices (see Table 9). The total condition concept accounted for 28% of the variance. Also, the correlation (N = 40) of the variables was .68 for the condition and action concept totals, -.22 for the goal and condition concepts, and -.34 for the action and goal concept totals.

The Variety of Concepts for each condition, action, and goal concept category were analyzed in a 2 x 2 (Age x Expertise) MANOVA for the situation interview. The results of the MANOVA indicated a significant effect for expertise, $F(3,34) = 6.20$, $p < .01$, with no significant age, $F(3,34) = 1.21$, $p > .05$, or interaction, $F(3,34) = 1.12$, $p > .05$, effects. The main effect of expertise was followed up by a stepwise discriminant analysis ($p = .05$). Only the variety of action concepts discriminated between experts and novices, $F(1,38) = 17.02$, $p < .01$, accounting for 31% of the variance, although, as in Total Concepts, experts had more action but slightly fewer goal concepts (see Table 9). Also, the correlation ($N = 40$) of the variables was .61 for the variety of condition and action concepts, -.16 for the variety of goal and condition concepts and -.15 for the variety of action and goal concept.

Overall, experts' sport-specific knowledge contained more and varied conditions and actions than novices. Based on the totals and the high correlations between actions and conditions, experts seem to exhibit knowledge with a more highly developed production system regardless of age.

Insert Table 9 about here

Quality of Concepts. The frequency scores for the qualities of each concept (for characteristics see Table 8) were analyzed to examine the featural qualities of the productions generated by the situation interview. The characteristics (frequency of occurence) of each category of knowledge (condition, action, and goal concepts) were analyzed by a Kruskal-Wallis test on rank scores for age and expertise levels. Also, to examine the interconnections in the knowledge structure, "unit" scores were analyzed by the Kruskal-Wallis technique.

The condition concepts regarding at least one condition (coded 2) other than those regarding the subject (e.g., the opponent's position) and two or more conditions (coded 3) beyond those regarding the subject were significant for level of expertise. Overall, child experts generated more higher level conditions than did child novices (see Table 10). All age effects were nonsignificant.

The quality scores of actions (see Table 8 for coding characteristics) were also nonsignificant for age effects. Novices generated significantly more inappropriate actions than did experts. The condition qualities were borderline significant, $p < .07$, for the frequency of appropriate actions (i.e., an action selected without any forceful qualities, coded as 1 in Table 10). As Table 10 indicates, experts generated more forceful actions (selection of an appropriate action with at least one forceful quality, coded 2). Overall, experts generated more appropriate and more forceful actions than did novices (see Table 10). Thus, experts were more sophisticated or elaborate than novices in knowing when or under what conditions to apply the actions or patterns of actions.

Frequency scores for the qualities of goal concepts were not significant for age or expertise levels with the exception of goal concepts pertaining to the subject and opponent. Novices produced significantly more goal concepts, coded 1, (see Table 8 for coding rules) than did experts (see Table 13). As a result, novices appear to be structuring their procedures in the lower level hierarchy of goals inherent in the game.

Linkages. Another way to examine the development of procedural knowledge is to consider the extent of linkages generated between and within categorical concepts. The total number of single units (e.g., a response denoting only a single action concept) was not significant for age or expertise based on the Kruskal-Wallis statistic. However, significant differences in expertise were denoted (see Table 11) as experts generated more double linkage categories (e.g., a response denoting one condition and two actions or a response containing one action and two goals). Also, experts generated significantly more triple and/or greater linkages (e.g., responses denoting at least two concept categories and at least one other concept). Overall, experts produced more sophisticated linkages within and across concept categories in terms of double and triple linkages than novices.

Connections. The frequency scores of the number of interconnnections between concepts were not significantly different between age or expertise levels as analyzed by the Kruskal-Wallace test.

However, child experts did indicate more interconnections between concepts than novices (see Table 11).

Insert Table 11 about here

Point Interview

The analysis of the point interview examined how an individual's knowledge structure was applied during actual game play. The same analyses outlined for the situation interview were also conducted examining the point interview, with the addition of: (a) examination of other comments classified as reactive, literal, not thinking, or concentrating, and (b) the interaction of a strong decision (the action selected) and the ability to execute this action during game play.

Total and Variey of Concepts. In order to determine which factors discriminate experts from novices during game play, a 2 x 2 (Age x Expertise) MANOVA was performed on the total number of concepts for the categories of condition, action, and goal. The results of the MANOVA indicated no significant effects for age, $F(3,34) = 0.36$, $p > .05$, expertise $F(3,34) = 2.03$, $p > .05$, or interaction, $F(3,34) = 0.36$, $p > .05$, effects, although experts had more total condition and action concepts (see Table 9) than novices. However, the results of the MANOVA for the variety of concepts indicated significant effects for expertise, $F(3,34) = 5.98$, $p < .01$, with no significant, age $F(3,34) = 2.64$, $p > .05$, or interaction, $F(3,34) = 0.28$, $p > .05$, effects. The main effect of expertise was followed up by a stepwise discriminant analysis ($p = .05$). Only the variety of action concepts significantly discriminated between experts and novices. The variety of actions accounted for 27% of the variance. Also, the correlation (N = 40) of the variables was .35 for the variety of action and condition concepts, .11 for the variety of condition and goal concepts, and .28 for the variety of goal and action concepts. Child experts generated a greater variety of action and condition concepts than novices (see Table 9).

The variety of action concept of knowledge was the maximal discriminator of expertise level with the experts increased availability of a variety of actions during game play. This follows predictions from learning models (e.g., Anderson, 1983) that it is easier to build up more conditions but requires extensive practice to change behavior (actions). These results, together with the correlation results, suggest experts had available a wider variety of actions that were important to the goal structure of the game situation.

Quality of Concepts. To examine the quality of concepts (condition, action, goal) produced during competition, frequency scores were classified in a manner similar to the situation interview (see Table 8 for coding rules) and analyzed in a one-way analysis of rank scores, Kruskal-Wallis Test. Following the same trend as the situation interview, age effects were not significant for the qualities of condition, action, or goal concepts produced. As predicted, expertise levels were significant for the qualities generated within all categories (condition, actions, and goals).

The quality of condition concepts denoted that experts produced significantly more conditions regarding themselves and other conditions (e.g., the opponent) and conditions regarding themselves and two or more conditions (see Table 12). Overall, experts produced more one condition and two or more conditions beyond those regarding themselves than did novices (coded 2 and 3 in Table 12).

The quality of action concepts generated by experts was significantly more forceful, and very forceful (see Table 8 for coding rules). That is experts generated actions with one or more forceful qualities (e.g., a groundstroke deep) and actions with two or more forceful qualities (e.g., a groundstroke deep with topspin down-the-line) than novices indicated by characteristics coded 2 and 3 in Table 12. Also, only novices indicated selection of inappropriate actions (coded 0 in Table 15).

Goal concepts were not significantly different regarding age or expertise (see Table 12). Borderline significance was reached in which experts generated more goals such as winning the point, game, or match (coded 2), $p < .07$, than did novices.

Linkages. The structure of linkages between and within concept categories generated during game play was significant in terms of experts producing more double linkage categores (i.e., a response containing two concept categories with at least two or more concepts within one of the concept categories). The Kruskal-Wallis test (see Table 11) denoted that experts generated more linkages between and within concepts than did novices. All other linkages were not significant for age or expertise effects.

Connections. The frequency scores of the use of connecting words or phrases between concepts were analyzed by a rank order one way ANOVA within age and expertise levels. The Kruskal-Wallis test indicated only the main effect of expertise was significant (see Table 11) as child experts exhibited more interconnections between concepts than novices.

Overall, the expert's more cohesive knowledge struture was more apparent during game play as opposed to the situation interview suggesting that experts have access to a more cohesive and integrated production system during game play.

Also, responses for point interviews were coded for comments generated other than those indicating the categorical concepts. These comments were classified and coded as: reactive (i.e., emotional statements such as "I'm mad"), literal (i.e., general statements denoting an account of the past events that just occured), not thinking (i.e., general statements denoting lack of concentration) and finally, concentration (i.e., generalized statements regarding a need to concentrate on the game). The results according to the Kruskal-Wallis test were significant for expertise levels in terms of literal, $\chi 2(1, N = 40) = 3.4$, $p < .01$, and concentration, $\chi 2(1, N = 40) = 6.66$, $p < .01$, comments. That is, novices generated more literal comments ($M = 3.4$, $S = 3.2$) than did experts ($M = 0.95$, $S = 1.4$). Further, experts were more aware of the need to concentrate ($M = 0.4$, $S = 0.8$) than were novices ($M = 0$, $S = 0$).

Agreements and Disagreements. The interaction of the action concepts regarding the selection of a response ("then") and the ability to execute this response ("do") were coded during games in terms of the number of agreements and disagreements between the action selected and the ability to carry out this action. Each individual's verbal report was examined in terms of their response selected and the execution of this action during actual game play. The frequency scores for agreements and disagrements were analyzed for age and expertise levels. The Kruskal-Wallis test denoted that experts, $\chi 2(1, N = 40) = 4.43$, $p <$

.05, generated more verbal agreements during competition (M = 2.4, S = 2.8) than did novices (M = 0.7, S = 1.1). Also, experts generated more verbal disagreements during competition, $\chi^2(1, N = 40) = 3.89$, $p < .05$, (M = 1.6, S = 2.1) than did novices (M = 0.6, S = 1.4). These findings suggest experts are at the stage of proceduralization (i.e., the formation of procedures) as they are verbalizing whether or not what they decided to do worked or failed to work (Anderson, 1981,1983). The novices on the other hand, viewed the problem situation or reasoned at more literal levels (generalized accounts or reiterations of what happened specifically).

These trends were also consistent with the game play behavioral coding. The performance components were examined in terms of the number of strong decisions and forceful executions coded as agreements and disagreements, any strong decision and unforceful execution. The total number of agreements during game play were significant for age, $\chi^2(1, N = 40) = 4.05$, $p < .05$, and expertise, $\chi^2(1, N = 40) = 9.52$, $p < .01$. The 12-13 year olds (M = 7.8, S = 4.8) were more able to execute their strong decisions than were the 10-11 year olds (M = 5.1, S = 4.4). Likewise experts (M = 8.8, S = 5.1)) were also more able to execute their strong decisions than were the novices (M = 4.1, S = 3.0). Also disagreements during game play were significant for expertise, $\chi^2(1, N = 40) = 25.15$, $p < .01$, as experts (M = 9.8, S = 4.7) had more disagreements between selection and execution of actions during game play than novices (M = 2.1, S = 1.9). There were no significant age differences for disagreements. The ability of the older children to execute their strong decisions indicates the skill component of execution may take longer to develop than the decision component.

Within experience levels, experts with higher levels of knowledge and skill exhibited more agreements. It is also interesting to note that disagreements were greater for experts in that strong decisions may not always be related to forceful executions. Further, novices may have fewer disagreements simply because they make few strong and forceful decisions (lack of knowledge) and they cannot execute the skills anyway (lack of skill). This trend was also evident in the correlations between the components of decision and execution in Phase 1.

The results of Phase 1 indicated that both cognition and motor skills contribute to the development of skilled performance. Experts regardless of age performed better than novices on tennis skill and knowledge; experts' decisions and executions (procedures and actions) were better during tennis game performance. The performance tests (knowledge, serve, and groundstroke) were also predictors of decision and execution ability during service and game play. Verbal reports were used to assess the bases of decisions during game play in Phase 2. The results were based on two measures of knowledge structure: what was stored (the total number, the variety, and the characteristics of concepts within condition, action, and goal concepts), and how it was stored (the number of connections between concepts and the linkages across and within condition, action and goal concepts). Overall, the experts' greater decision-making ability during game play may be considered as directly related to their knowledge structure. Experts, regardless of age, exhibited a more cohesive and integrated knowledge structure allowing more efficient and effective accessibility to their knowledge.

Verbal protocols indicated that experts as compared to novices, focused on higher level concepts, had more interconnections among these concepts, and had available a wider variety of condition concepts and action concepts that were important to the goal structure of the game. Further, this variety of procedures (i.e., more alternative actions) enabled experts to be more flexible using a variety of condition - action responses. The novices, however, were more rigid in their approach due to their limited productions.

As noted earlier, there were no expert/novice differences in the overall total number of concepts (condition, action, goal). Differences did occur as experts reported a greater variety of actions with more forceful qualities and more conditions regarding themselves in addition to one or more conditions. As a result, this "if-then" (i.e., condition/action) development of the expert's procedural knowledge may be influential in the development of the "if- then-do" productions. For instance, expert/novice differences were noted during the point and situation interviews in action concepts related to the goal of execution of the task (i.e., parameter adjustments in task performance). Overall, novices had two major labels for their actions: a serve and a groundstroke even when situations (either in actual play or in the situation interview) called for other actions such as a volley, overhead smash, or an approach shot. The novices made generalizable task or action related statements such as "I was just trying to hit it" without any qualitative context-dependent characteristics. This was not the case, however, for experts as they had distinct labels for specific response selections (actions). Also, expert's productions included the parameters (e.g. spin, direction, and/or placement), the mechanics of the task production (e.g., the angle of the racket face) and/or execution goals (e.g., trying to hit groundstrokes at least 3 feet above the net). This suggests that experts have procedural knowledge which includes condition-action linkages, as well as procedural knowledge which incorporates the concepts of execution (do).

As reviewed, the characteristics of an expert includes the ability to select the appropriate action (condition-action side) and the ability to execute the decision that was made (execution side). This interaction of sport specific cognitive and motor skills not only increased in terms of the behavioral coding, but was observable in the point interviews. Experts were more aware of the cognitive/motor interaction as they stated appropriate conditions and forceful responses together with an examination of why (or why not) they were able to carry out (execute) their desired reponse. Novices on the other hand spoke of execution ability in goal related or generalized terms without any context related (condition-action) comments. This suggests, that not only do productions include condition-action concepts, but also execution and perhaps storage of complete units of "if-then-do productions". Further, the interaction of sport specific cognitive and motor skills may increase with an increased awareness or interpretation of the end product (execution) together with the context decision that initiated the response.

General Discussion

Theoretically, this study examined the influence and development of sport knowledge and how this knowledge was applied. The results indicated experts' skilled performance was influenced by their knowledge structure which allowed them more effective use of their knowledge during game play (i.e., greater decision-making ability).

The interaction of content knowledge (declarative) with procedural knowledge was evident in the situation and point interviews. The behavior of expert and novice players seems to incorporate the principles that govern learning (e.g., Anderson, 1981, 1983). It appears that novices are still forming a declarative base of knowledge and how to solve the problems (make decisions during game play) which follows along with the characteristics of the development of procedural knowledge (e.g., general interpretive procedures). The interviews indicate that novices approach the problem in a general manner (evidenced in their procedural knowledge structure) with limited declarative knowledge. As a result, novices must keep active in memory the features of the problem and the very general goal of finding a way to solve it. Information must be searched out (i.e., interpretive procedures) and brought into working memory. Overall, novices have slower access and a more generalized approach to solving the problem. Further, novices may have been unable to use procedural references during game play because they did not exist (denoted in the situation interview)

As expertise is developed, the general productions appear to be replaced with more specific knowledge (specific condition/action productions) embedded in them. Experts, at the level of this study, appear to be in the stages of knowledge compilation in which they are composing (beginning to collapse several productions that follow each other in solving particular situations during game play) and/or proceduralizing (creating new productions) (for a review see Anderson, 1983). Another interpretation (for a review see Chi & Rees, 1983) is that experts are building an extensive knowledge structure which allows them quicker access (activation spreads) to more information in less time in response to certain conditions. As predicted, the present findings were similar to other knowledge base research in terms of expert/novice differences in the representation of domain knowledge (i.e., experts' more highly developed knowledge structures) (e.g., Chi & Koeske, 1983; Chiesi et al., 1979; Gobbo & Chi, 1986; Spilich et al., 1979).

The results of this study seem to follow within these learning frameworks. Specifically, the verbal and behavioral results seem to adhere to Fitts and Posner's (1967) general stages of skill learning and the detailed description of the within stages of learning in Anderson's (1983) computer simulated learning model. That is, experts according to the verbal and behavioral results are in the stages of compilation or association-automation (Anderson, 1981, 1983; Fitts & Posner,1967, respectively) de oted by their strong condition and forceful action productions which sometimes are successfully executed and at other times not. The novices, however appear to be at the early stages of learning, lacking minimal condition-action linkages with minimal action concepts (e.g., Fitts & Posner's cognitive stage). If they reported "do" statements, they were generalizable and execution driven, rather than, like the experts, context driven "if-then-do" statements. Experts with greater decision making ability during game play also exhibited production protocols containing qualitatively different "if-then-do" statements and/or more higher level macro-production statements (fewer productions to accomplish the same thing). Also, the investigation of linkages indicated that experts have greater access to their knowledge structure within and across productions. Novices (exhibiting poorer decision making abilty during performance) approached the problem solving situation (as evidenced in interview protocols) by incorporating a limited number of recognizable conditions ("if") and few alternatives to solving the problem ("then") with a limited and generalized approach toward execution ("do").

The interaction of declarative and procedural knowledge and how they develop to form productions should continue to be examined in order to understand the development of expertise. Sport domains as opposed to verbal learning, may provide a unique environment to examine how procedures develop and influence expertise. In the verbal domain, as opposed to the domain of sport, actions may not be readily observed (Anderson, 1983). Taken together, the present findings and how they model the theoretical frameworks for learning research (whether developmental, Chi & Rees, 1983; computer simulated, Anderson, 1983; or motor skill, Fitts & Posner, 1967) into sport domains may reveal the development of the declarative/procedural knowledge interaction (the development of knowledge structure) and its influence on performance.

Instructors in all domains frequently spend more time building a foundation of declarative knowledge as opposed to procedural knowledge. The domain of sport may prove a viable means to investigate the development of productions as it is more easily modeled in skill than in verbal learning. In sport, not only is there concern with correct decisions but the ability to execute the action as well which in most cases is directly observable. As a result, the sport domain may offer more insight into how we might teach or develop a learner's productions.

Within sport, for example, coaches try to formulate player's productions (e.g., "if this condition exists, then you do this") and instruct them in terms of cues (e.g., "watch your opponent's racket - if they open their racket face, then you should position yourself for a lob").

Further, the interaction of the production systems during sport performance (i.e., how to select actions x how to carry out actions) may also increase our understanding of the development of expertise. In this study, some experts were not only able to detect errors in terms of inapproriate condition responses, but also, in the parameters of execution responses. Experts denoted where the problem occurred (i.e., decision or execution) and were able to correct it. However, this was not the case for all experts which adheres to the logic that motor skill learning requires a tremendous amount of practice. But after the appropriate amount of practice, experts do appear to reach stages of automaticity. Conceptually, these observable stages of production development (i.e., the declarative/procedural/execution interaction) may reflect both the process (e.g., Schmidt, 1975) and perception/action (e.g., Gibson, 1966; Turvey, 1977) theories of learning. This merge in orientations may occur in that the learner begins in a process oriented approach and moves through the stages ultimately reaching a more stimulus-response type of behavior. The process of learning is this building of the condition-action-execution productions. Whether or not productions are developed by practicing the execution side ("do") to reach an autonomous stage allowing the condition-action ("if-then") side to be built or by practicing the condition-action side ("if-then") to reach an autonomous stage allowing the execution side to be built, or whether the "if-then-do" procedure is developed as a unit, are viable questions in all areas of learning.

The results of this study indicate "if-then-do" production units influence decision-making ability during game play. As a result, instructors may enhance the development of these units (i.e., knowledge structure) by identifying and conveying to learners specific "if-then-do" situations which may occur during performance. Expertise may be developed by learners practicing the selection and use of specific and alternative "if-then-do" units.

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Table 1

Characteristics of tennis experience by age and expertise level

Age			Practice[a]	Play[b]	Lessons[c]	Length[d]	Family[e]	Camps[f]	Tournament[g]
12-13	expert	M	4.4	4.8	58.4	29.4	2.8	228.8	15.7
	(n=10)	S	1.1	1.4	36.4	11.5	1.5	140.4	17.7
	novice	M	1.9	1.7	22.5	19.5	1.8	3.0	0.0
	(n=10)	S	1.4	1.2	25.4	11.1	1.2	3.7	0.0
10-11	expert	M	3.9	2.4	36.5	32.4	2.6	133.1	11.9
	(n=10)	S	1.2	2.0	23.2	19.2	0.7	62.4	10.8
	novice	M	2.7	2.3	22.0	26.4	2.4	11.8	0.0
	(n=10)	S	2.3	2.2	25.9	14.4	0.7	16.8	0.0

a practice sessions per week

b play sessions per week

c total weeks of lessons

d total months of playing experience

e family members who play

f number of weeks of camp/club attended

g total number of tournaments participated in

Table 2

Means and standard deviations for experts and novices for the knowledge, serve skill, and grounsdstroke skill tests

		Novice (n=20)	Expert (n=20)
Knowledge Test a	M	47.4	65.7
	S	15.2	10.9
Serve Testb	M	12.3	28.2
	S	6.2	7.5
Groundstroke Testc	M	8.9	19.7
	S	4.3	4.8

a percent correct

b total points

c total points

Table 3

Standardized canonical correlation coefficients for the analyses of the serve and the game play following the serve

	Standardized Canonical Coefficients	
	Serve Play Function 1	Game Play Function 1
Knowledge	0.39	0.42
Serve[a]	0.77	----
Groundstroke[b]	----	0.69
Control[b]	----	0
Decision	0.96	0.65
Execution	0.06	0.41

a only for serve analysis

b only for game play analysis

Table 4

Prediction of decisions and execution from the scores of each test for serve play

	Standardized coefficients	Partial correlations	Semipartial correlations
Decision			
knowledge test	.28	.33	.26
serve test	.53	.31	.23
Execution			
knowledge test	.08	.11	.09
serve test	.51	.23	.21

Table 5

Prediciton of decisions and exectuion from the scores of each test for game play

	Standardized coefficients	Partial correlations	Semipartial correlations
Decisions			
knowledge test	.30	.49	.40
groundstroke test	.55	.31	.19
Execution			
knowledge test	.33	.44	.38
groundstroke test	.47	.22	.14

Table 6

Classification rules for coding the point and situation interviews.

CONCEPT: A concept is defined to be a unit of information about response selection in the context of a game situation. Each unit of information will be classified as a strategic, action, or goal concept.

STRATEGIC CONCEPT: ("if") A unit of information that specifies when or under what conditions to apply the action or patterns of actions to achieve the goal. Strategic concepts may refer to an individual's consideration of an opponents's strength, his own position, or his prior shot, regarding his selection of actions in game situations. Strategic concepts are usually related to the type of shot selected or positioning on court. Overall, strategic concepts are abstract concepts specifying when or under what conditions to apply the action or patterns of action.

ACTION CONCEPT: ("then") A unit of information which refers to the action selected or patterns of action selected which produce goal related changes in the context of a game situation. They may be characterized by the action itself (e.g., a particular stroke selected, or a certain movement to obtain a specific position on court) and also, they may include qualitative characteristics such as the type of action (e.g., direction, placement, speed) indicating forceful qualities as outlined in the decision rules coded for the components of performance in Phase 1.

GOAL CONCEPT: ("to") A unit of information which refers to the games goal structure usually hierachally organized. Goal concepts such as winning the point, or executing the skill, keeping the ball in play, making the opponent run, and preventing an opponents aggressive shot.

Table 7

Some examples of possible knowledge categories

CONDITION CONCEPTS	ACTION CONCEPTS	GOAL CONCEPTS
His Strength	Serve	Keeping the
Weakness		ball away
Position	Return of Serve	
Prior Shot		Preventing
	Groundstrokes	aggresive
His Opponent's		shots
Strength	Lobs	
Weakness		Winning the
Position	Passing Shots	point
Prior Shot		
	Drop Shots	
Shot Type	Approach Shots	Executing
		the skill
Service Type		
	Volley	Getting the
Position Type		ball in
Forcing	Smash	
Central		Keeping the
Game Status	Position Moves	ball in play

Table 8

The decision rules for coding the quality of each concept for the point and situation interviews

Concept Quality: Each concept will be coded according to the quality of the concept in the context of the interview situation or point situation.

Category	Code	Decision Rule
Condition Concept:	0	= inappropriate condition
	1	= appropriate only regarding himself
	2	= appropriate and forceful-himself and one other
	3	= apprioriate and very forceful-himself and 2 others
Action Concept:	0	= inapproriate action
	1	= approriate but weak -no forceful qualities only execution mentioned
	2	= appropriate and forceful -1 forceful quality
	3	= approriate and very forceful -2 or more forceful qualities
Goal Concept:	0	= skill and himself -execution, getting it in, keeping the ball in play
	1	= himself and opponent -keeping the ball away, preventing opponents aggressive shots
	2	= winning the point, game, match

Table 9

Means and standard deviations for the overall total and different concepts by expertise levels for the situation and point interviews

	Experts (n=20)		Novices (n=20)	
	M	S	M	S
Situation Interview				
Total Concepts				
Condition	7.7	4.0	3.7	2.4
Action	7.3	2.9	5.0	2.3
Goal	3.4	2.1	6.0	10.5
Different Concepts				
Condition	4.6	2.0	2.5	1.8
Action	4.2	1.0	2.8	1.3
Goal	2.3	1.2	2.8	1.7
Point Interview				
Total Concepts				
Condition	7.0	5.2	4.1	4.5
Action	3.8	3.3	2.0	2.8
Goal	3.9	2.7	3.0	3.1
Different Concepts				
Condition	3.2	1.8	2.0	1.7
Action	2.6	1.7	1.0	0.9
Goal	2.0	1.2	1.4	1.2

Table 10

<u>Means, standard deviations, and the Kruskal-Wallace (chi-square approximation) test by expertise levels for the situation interview</u>

	Experts (n=20)		Novices (n=20)		
	M	*S*	*M*	*S*	χ^2_a
Quality					
Condition					
0	0.5	1.8	0.3	0.6	0.52
1	2.8	2.0	2.0	1.5	1.57
2	3.9	2.9	1.6	1.5	7.21**
3	0.2	0.4	0	0	4.33*
Action					
0	0	0	0.8	1.6	6.83**
1	4.2	2.5	2.7	1.8	3.31
2	2.4	1.7	1.3	1.1	4.92*
3	0.7	0.9	0.4	0.9	2.12
Goal					
0	2.3	1.6	2.7	1.1	0.62
1	0.3	0.7	0.8	0.8	4.92*
2	0.4	0.6	0.2	0.5	1.12

* $p < .05$

**$p < .01$

a df = 1, *N* = 40

Table 11

Means, standard deviations, and the Kruskal-Wallace (chi-square approximation) test by expertise levels for concept linkages and number of connections between conceptsfor the situation and point interviews

	Experts (n=20)		Novices (n=20)		
	M	S	M	S	χ^2_a
Situation Interview					
Linkages					
Single Units	1.9	1.6	1.9	1.3	.01
Double Units	1.9	1.1	1.0	0.9	6.93**
Triple Units	0.8	0.8	0.3	0.5	4.80*
Connections	9.9	6.7	6.3	3.7	2.58
Point Interview					
Linkages					
Single Units	7.6	3.6	6.4	4.5	1.10
Double Units	1.2	1.6	0.3	0.7	8.05**
Triple Units	0.1	0.2	0	0	1.00
Connections	3.7	3.5	1.2	2.0	8.59**

* $p < .05$

** $p < .01$

a df = 1, N = 40

Table 12

Means, standard deviations, and the Kruskal-Wallace (chi-square approximation) test by expertise levels for the point interview

	Experts (n=20)		Novices (n=20)		
	M	S	M	S	χ^2_a
Quality					
Condition					
0	0.1	0.2	1.1	1.6	10.17**
1	3.2	2.4	2.1	2.8	3.14
2	3.3	3.8	0.8	1.7	8.49**
3	0.4	0.8	0	0	4.32*
Action					
0	0	0	0.1	0.2	1.00
1	1.6	1.8	1.1	2.1	2.81
2	1.8	2.0	0.9	1.5	4.97*
3	0.6	1.0	0	0	8.21**
Goal					
0	2.6	2.1	2.3	2.6	0.75
1	0.2	0.4	0.1	0.2	1.08
2	1.1	1.3	0.6	1.1	3.22**

* $p < .05$

**$p < .01$

a df = 1, N = 40

Appendix A

Knowledge Test

The written test was administered to 31 advanced and novice male tennis players ages 8-13 attending the first camp session. A KR-20 estimate indicated internal consistency of .79. The median of the index of difficulty was .58. Forty-eight of the 50 items (96%) had an index of difficulty between .35 and .90. Forty of the 50 items (80%) had an index of discrimination of .20 and greater (range .20 to .80) with the remaining 10 receiving .10 or greater as an index of discrimination. The test was also shown to discriminate between advanced and novice tennis players regardless of age. Construct validity (known group difference method) was indicated in a 2 x 2 ANOVA (age x level of expertise). The expert group consisted of 5 8-10 year-olds and 9 11-13 year-olds. The novice group contained 7 8-10 year-olds and 10 11-13 year-olds. Experts were found significantly different from novices, $F(1,27)= 10.44$, $p<.01$, with no significant age, $F(1, 27)= 0.12$, $p>.05$, or interaction, $F(1,27)= 0.01$, $p>.05$, effects. The mean for novices was 62% correct (S=11%) and the mean for experts was 74% correct (S=9%). The percent variance accounted for by the group difference was 25%.

Some items in the original knowledge test were revised for questions receiving an index of discrimination below .20. Again, experts found the revisions valid for content. The revised knowledge test was administered to 21 male tennis players age 8-13 attending the second camp session. The results indicated the knowledge test was a reliable measure of tennis knowledge, KR-20=.81. The median index of difficulty was .50. Forty-eight of the 50 items (96%) had an index of difficulty greater than .23. The mean of the index of discrimination was .31. Forty of the 50 items (80%) had an index of discrimination greater than .20.

Overall, these results indicate that the knowledge test was reliable and valid measure of tennis knowledge for boys ages 8-13 years-old.

Skill Tests

Skill testing was administered by the experimenter (an expert) on a regulation tennis court to each individual in small groups of 3 to 4 subjects. Groundstroke skill was measured by having players position themselves at a point behind the center service stripe on the baseline. The tester, the experimenter, delivered a total of 24 balls (judged good by the experimenter, an expert) to each player who attempted to stroke 10 forehand and 10 backhand groundstokes. The trials consisted of 1 practice followed by 5 scored cross court and 1 practice followed by 5 scored down the line for each groundstroke. In order to standardize the procedure, the experimenter hit all balls to all players. Scoring of the forehand and backhand groundstroke consisted of marked number zones (designated 3, 2, and 1) with the higher score nearer the baseline. The total possible points for groundstrokes was 60 points.

Serve skill was measured using procedures similar to the groundstroke skill test in which the serve was scored on the bases of the target area hit. In performing the service test, the subject assumed his service stance at a marked service position and first served into the right service court consisting of two target areas representing a forehand and backhand service zone, (number zones designated 3, 2, and 1) with the higher score nearer back service line. Serve trials consisted of 1 practice and 5 scored serves into each zone for both the right and left service court. A total of 60 points for each service court was possible.

The scores for each skill test were analyzed separately for each age level in a 2 x 2 (subject x day of testing) ANOVA. Intraclass reliability estimates for the serve and groundstroke skill tests were .91 and .72 for the younger age group, and .87 and .88 for the older age group. Table 13 indicates the means and standard deviations for each age group for the serve and groundstroke skill test trials. The novice group consisted of 7 8-10 year-olds and 11 11-13 year-olds. The expert group consisted of 7 8-10 year-olds and 9 11-13 year-olds. In a 2 x 2 ANOVA (age x level of expertise) experts were found significantly different from novices in the groundstroke skill test, $F(1,30) = 17.55$, $p < .01$, w2 = 47%, with no significant age, $F(1,30) = 3.60$, $p > .05$, or interaction effects, $F(1,30) = 0.11$, $p > .05$. Similar results were indicated for the serve skill test as experts were significantly different from novices, $F(1,30) = 18.71$, $p < .01$, w2 = 53%, with no significant age, $F(1,30) = 0.16$, $p > .05$, or interaction effects, $F(1,30) = 0.48$, $p > .05$. The means and standard deviations for each group for the groundstroke and serve skill test are presented in Table 14.

Table 13

Means and standard deviations for each age group for the serve and groundstroke skill test trials

		Groundstroke		Serve	
		Day		Day	
		1	2	1	2
Age					
8-10	M	11.2a	12.6	14.2b	14.3
(n=14)	S	3.8	4.1	4.3	4.1
11-13	M	11.4	12.4	14.2	14.6
(n=20)	S	5.6	5.1	5.6	6.5

a possible score is 20 trials x 3 points = 60

b possible score is 20 trials x 3 points = 60

Table 14

Means and standard deviations for each age group for the groundstroke and serve skill tests by expertise level

		Skill Test			
		Groundstroke		Serve	
	N	M	S	M	S
8-10 Year Olds					
Novices	7	10.0	2.7	11.3	2.2
Experts	7	15.1	3.7	17.3	3.4
11-13 Year Olds					
Novices	9	9.6	4.3	10.3	4.0
Experts	11	15.7	4.1	19.1	7.2

Game Skills

A summary of the decision rules for the coding of the components of performance during the serve and game play are presented in Table 15. Four experts and four novices were videotaped playing six tennis games within two age levels (10-11 and 12-13 years old) participating in a junior tennis program. Interrater reliability was established by two experts observing 4 of the 6 games with each player serving and receiving serve twice. Four players were selected randomly from each experience and age level and coded on each category of the observational instrument for the serve and game play following the serve. The behaviors coded were collapsed across all 4 games for each individual. Reliability was estimated by the formula, # of agreements/(# of agreements + disagreements) x 100 = %. Intrarater reliability was estimated by an expert coding and re-coding all 8 players on separate occasions using the same procedures indicated in the interrater reliability condition.

Overall, intrarater reliability estimates (N=8) for the serve were .94 for decision and .88 for execution. During game play reliability was .99 for control, .87 for decision and .92 for execution. Likewise, interrater reliability estimates (N=4) for the serve were .99 for decision and .98 for execution, while the estimates were 1.00 for control, .98 for decision and .99 for execution during game play. The coding instrument was considered reliable for all categories as interrater reliability estimates ranged from .94 to 1.00 while intrarater reliability estimates ranged from .82 to 1.00.

Table 15

Summary of decision rules for the coding of the components of performance during the serve and game play

The Serve

Decision

Coded as 1: A strong decsion if the player made an appropoqriate decision in the context of a given situation. The action is selected considering the player's and opponent's position.

1. Any attempt made to serve the ball with depth, spin, speed, or placement in order to force a weak return;
2. Any attempt made to serve the ball to an open area of the service court due to the opponent's position, into the opponent, or to the opponent's weakside in order to force a weak return.

Coded as 0: If the player made a weak decision in the context of a given situaition. The action is selected considering only the player's position with putting the ball "in play" as the main goal

1. If the server was standing far from the center mark and served the ball to the opponent's strong side or to the middle of the service court;
2. If the server placed the ball in the court in a soft lobing manner allowing his opponent to return the ball offensively;
3. If the server attempts a first serve with erratic power, followed by a soft pushing second serve;
4. If the server serves off balance and without control due to a poor toss;
5. If the server does not attempt to serve to the open area of the court, or weakside allowing the opponent to return the ball offensively.

Table 15 con't

Execution

Coded as 3: A serve that is successful and forcing due to placement, speed spin and/or depth usually placing pressure on the opponent;

Coded as 2: A serve that is successful, yet not forcing due to lack of placement, speed, spin and/or depth placing litttle pressure on the opponent.

Coded as 1: An unsuccessful serve that is ruled long or wide.

Coded as 0: A netted serve.

Game Play Following Serve

Control

Did the player gain and maintain control of the tennis ball?

Coded as 1: If the player contacted the tennis ball with his racket enabling him to select an action (stroke).

Coded as 0: Actions such as missing the tennis ball, illegal contact (e.g., body parts, carrying the ball) or inability to control the ball resulting from an opponents good shot or the player's poor footwork which do not allow the player to select an action.

Table 15 con't

Decision

Did the player make an approporiate decision in the context of a given situation?

Coded as 1: A strong decision was coded as selection of an appropriate action (offensive or defensive) according to the player's position, his opponent's position, and the position of the ball. The action usually places pressure on the opponent which may force the opponent to move (e.g., sideways, up or back), to play his weakside (e.g., placing the ball to his backhand), and/or to stay back behind the baseline (e.g., placing the ball deep). Also the action may enable the player to recover his position (e.g., a defensive lob).

Coded as 0:

1. A weak decision was coded as selection of an inappropriate action according to the player's position on court, how much angle is available, and the oppoonent's position on court (e.g., a groundstroke returned to the opponent at the net without any attempt to pass, lob or use other strokes that would place pressure on the opponent) usually allowing the opponent to play an aggressive shot.

2. Selection of an appropriate action within the context of only the player's position with the goal of putting the ball "in play", without considering the location of the ball and/or the opponent's position. This action usually allows the opponent to return the ball easily (i.e., requiring little movement), stroking on his strong side with minimal effort.

Table 15 con't

Execution

Did the player execute the decision successfully?

Coded as 3: A forcing shot usually moving the opponent (e.g., playing to his weakside) which may place pressure on the opponent forcing a weak return

Coded as 2: A shot which places little pressure or non-forcing actions on the opponent (e.g., the opponent has the opportunity to set up a strong return with minimal effort).

Coded as 1: A forced error which consists of a point lost as a result of the opponent's good shot

Coded as 0: An unforced error which consists of a point lost as a result of the player's mistake rather than the opponent's good shot

Point and Situation Interviews

Performance reliability on 8 subjects was obtained during the pilot work. The subjects were filmed twice (i.e., with and without verbal reports) playing 6 games during each filming. Four experts and 4 novices were coded on the components of performance during each filming. The scores for each component of performance for serve and game play were analyzed separately in a 2 x 2 (Expertise x Filming) ANOVA with repeated measures on filming. A reliability estimate for each dependent measure (i.e., decision and execution) was obtained through intraclass correlation and were .99 and above in all analyses for the serve and game play.

Interrater reliability was calculated for the situation and point interviews in order to determine the consistency in identifying the same number of behaviors and in judging the quality of these behaviors. Interrater reliabilty of the situation interview and the point interview was determined by 2 experts classifying responses of 10 of the 40 subjects (5 randomly selected subjects each for the situation and point interviews). The behaviors coded for each category of the verbal coding instrument (i.e., total concepts, different concepts, quality concepts, and unit formation) were collapsed across all questions for the situation interview and collapsed across all four games for the point interview for each individual. Reliability was estimated by [# of agreements/(# of agreements + disagreements)] x 100 = % for each category. The same procedures outlined in Phase 1 were followed. Intrarater reliability was conducted on 10 subjects (5 for the situation and 5 for the point interviews) coded on separate occasions using the same procedures indicated in the interrater reliability condition. The coding instrument was considered reliable for all categories as interrater reliability ranged from .93 to 1.00 while intrarater reliability was 1.00 for all categories. The remaining protocols were scored by one individual.

Appendix B

Extended Review of Literature

The Development of Expertise: Knowledge Base and Performance

The leading strategy for the study of development to date is through models adhering to general information processing (e.g., Kail & Hagen, 1977; Naus & Ornstein, 1983; Ornstein, 1978; Thomas, 1980, 1984). These models, typically, include 3 stages: a sensory store, short term store (working memory) and long term store (knowledge base). Tests of the components of developmental information processing models were, until recently, conducted within a unidirectional flow model. A large amount of research was directed to the short term memory component as a more effective short term store helps to synthesize and processlinformation in long term store. Consequently, knowledge base appeared to developed in a linear fashion across age. As a result, developmentalists focused most research efforts on the structural limitations of the capacity of short term memory (see Pascual-Leone & Smith, 1969) and failure to produce and effectively use control processes (i.e., general strategies that are in direct control of the processor and found in working memory) such as rehearsal strategies (see, Chi, 1976; Thomas, 1980, 1984 for reviews) or using metacognitive strategies such as monitoring (see, Brown & Deloach, 1978; Flavell, 1976), with little attention directed towards previous experience (i.e., an increase in the knowledge base). Overall, researchers investigating the components of the information processing models considered knowledge base to be a "universally" age related deficite inherent in children's information processing systems.

This was not the case, however, when investigators began to examine areas of domain expertise. In fact, domain related knowledge in some instances diminished all other age differences in memory and task performance when comparing child experts with adult novices (e.g., Chi, 1977, 1978; Chi & Koeske, 1983; Lindberg, 1980). As a result, researchers of human learning and memory are realizing multidirectional flow models (i.e., an interaction of the model components) are necessary for assessing memory and task performance. This also requires validation of the entire research setting as variables interact and bear complex relations to memory phenomena. Overall, memory phenomena observed depend on the characteristics of the subjects used, the testing conditions provided, the kinds of materials selected, and what kinds of criterion measures are obtained (Jenkins, 1979).

How expertise is acquired has become a question of concern for researchers interested in a general cognitive theory of knowledge base development and for those interested in enhancing performance of children and adults in verbal and/or sport skill acquisition. The definition of expertise is straight forward, but the explanation of expertise in terms of cognitive factors remains illusive. This review concerning knowledge base will first focus on conceptualizing knowledge base through semantic frameworks. Next, an overview of studies examining children's knowledge base in the verbal literature will be presented in order to investigate the role of knowledge base in developmental processing differences. Also, the ways experts and novices differ across various domains of knowledge will be reviewed in order to examine the characteristics and development of expertise. Finally, recent sport specific knowledge research is reviewed to examine the influence of sport knowledge in the development of sport expertise. Future directions will consider new approaches to ultimately increase understanding of the relation between knowledge base and performance.

The Conceptualization of Knowledge

What changes, in terms of knowledge base development, as individuals attain increasing competence has been examined within various research paradigms. Researchers contrasting experts and novices in specific domains generally speak of an experts superior performance in terms of structural differences. The term structural is somewhat confusing, and for purposes of this review structural knowledge will refer to changes in the properties of the nature of the representation which consists of nodes and links (Chi & Rees, 1984). In otherwords, changes in the structure of knowledge with experience refer to the configuration of nodes and links (i.e., the number of links, strength of the links, and the internal cohesion of the network) rather than the number of nodes or mode of representation.

Memory theorists, have conceptualized various semantic frameworks in many ways similar to computer models (e.g., Anderson, 1976, 1982; Norman & Rumelhart, 1975). Some regard the structure of knowledge base as more generic in terms of the knowledge domain such as Chi's (1982) procedural, declarative, and strategic knowledge. Other frameworks are more content specific such as Chiesi, Spilich, and Voss's (1979) hiearchial organization based on the goal structures of a sport domain (i.e., baseball knowledge).

In the generic model, both declarative (knowledge of factual information) and procedural (knowledge of how to do things) are domain specific. Strategic knowledge is considered as general mnemonic rules or strategies applicable across a wide variety of domains. Although evidence has determined the expert child is capable in some cases or overriding all other developmental differences (e.g., Chi, 1977, 1978), this concept of the development of general strategic knowledge allows for Flavell's (1978) age related production deficiencies noted in children. That is, in most cases, children will have less content and strategic knowledge and fail to produce a workable strategy as spontaneously or in the same way as adults (e.g., Bellmont & Butterfield, 1971; Gallagher & Thomas, 1984, 1986).

The hierarchial structure proposed by Spilich, Vesonder, Chiese, and Voss (1979) and Chiesi, Spilich, and Voss (1979) was derived from the nature of their experimental domains. They investigated sport (i.e., baseball) knowledge and proposed hierarchial levels were formed according to the goal structure of the game (e.g., winning) with setting events consisting of sequences of game states (the existing conditions in a game at any given time) and game actions (an action or series of actions occuring during the course of the game to produce a change in the game state). An example of a game state would be, "two outs runners on first and third". A game action example could consist of "a hit usually results in at least one runner on base". Knowledge is used to execute game actions which will produce changes in game states to accomplish the appropriate goal or subgoal.

The declarative/procedural knowledge dichotomy may be hazardous in the area of motor behavior. In sport, Thomas, French, and Humphries (1986) feel, it is impossible to distinquish between the two as a procedure or production system could refer to a series of if-then statements that would apply to a certain situation or to the control of a series of movements (i.e., by a motor program). As a result, Thomas et al.(1986) feel, the hierarchial goal structure may be more conceptually productive in the area of sport performance.

Knowledge Base and Developmental Processing Differences

Findings in the verbal literature examining knowledge base indicate:

1. the recall of newly presented material may vary according to one's prior knowledge of the presented material (e.g., Brown, Smiley, Day, Townsend, & Lawton, 1977; Chi & Koeske, 1983),

2. changes in knowledge base may reflect developmental differences rather than age-related differences attributed to the capacity of short term memory or to the use of control processes (e.g., Bjorkland & Zeman, 1982; Brown & DeLoache, 1978; Chi, 1982; Huttenlocher & Burke, 1976; Markman, 1979; Ornstein & Naus, 1983),

3. domain related knowledge may diminish all other age differences when comparing child experts with adult novices (e.g., Chi, 1977, 1978; Chi & Koeske, 1983; Lindberg, 1980) and

4. children's reasoning abilities are due to knowledge structure rather than abstract skills of reasoning acquired with maturity (e.g., Gobbo & Chi, 1986)

Early studies examined knowledge base development in constructive memory paradigms. Typically, a story was presented and subjects were asked to recall it. Within this paradigm, Brown et al. (1977) found older children with more knowledge of the to-be-remembered material, were able to recognize the relation of the new information to their existing knowledge.

In some instances, knowledge base development was considered the causal factor of what was previously thought to be age-related capacity or strategy differences. In two recall studies, when the experimenters used meaningful stimuli, first graders (Bjorkland et al., 1982) and kindergartners (Chi, 1982) were found capable of using adult-like clustering and spatial systems to cue memory. Examining these results, Chi (1982) proposed that powerful mnemonic strategies may be acquired only after people thoroughly know the to-be-remembered material. Differences in digit span (capacity differences), formally attributed to children's lack of rehearsal skills, were also attributed to differences in the to-be-remembered material (knowlege base). Similarly, Huttenlocher et al. (1976) found primacy effects (a sign of rehearsal) were as evident for 4-year-olds as 11-year-olds. They postulated lack of knowledge base as the causal factor of shorter spans, rather than rehearsal, as children knowing less about the items required more time to attend to the items.

Children are more likely to have "generalized" metacognition deficites as they, more often than adults, find themselves in a problem solving situation without the necessary knowledge about how and what to think under new circumstances. However, this is not necessarily age related. Gross inexperience presents the same problem in which metacognition is similar in adult novice chess players (Chi, 1978) as well as very young card players (Markman, 1979). Brown and DeLoache (1978) speculate as one progresses towards expertise (i.e., learning the necessary rules and subprocesses), a trend of self-regulation follows little self-regulation, active deliberate self-regulation, and finally automization as a result of overlearning (e.g., Simon & Simon, 1978).

Chi's work (1977, 1978) was instrumental in demonstrating the influence of specific content knowledge regardless of age. Child experts demonstrated, in a specific content (chess), the ablity to out perform adult novices even when they lacked sophisticated mnemonic strategies. Chi (1978) compared 10-year old chess experts with adult chess novices. The task consisted of a 10 s presentation of chess pieces organized on a chess board followed by a reproduction test on an empty chess board. The children exhibited superior short term memory for chess configurations when compared to the adult novices. Opposite this, these same adult novices demostrated the usual superiority of recall when administered a backward digit span task. Naus and Ornstein (1983) feel these results were primary in linking the change in knowledge base to the performance of children's developing memory strategies. Developmetalists are now examining the role of knowledge base in terms of develpmental processing differences. The changes in knowledge base as individuals attain increasing competence are being explored.

The ability of the knowledge base to reduce well known developmental differences in memory performance was also examined by Lindberg (1980). He varied the encoding strategies (e.g., experimenter instructions) within an incidental learning paradigm for kindergarten, sixth grade, and adult subjects. The results indicated conditions which equated subjects along the dimension of their knowledge base increased recall. Lindberg (1980) in a second experiment replicated Chi's (1978) study and found similar results as children with greater knowledge of the to-be-remembered material (i.e., names of cartoon characters) exhibited superior recall compared to the adults.

Chi and Koeski's (1983) dinosaur study advanced developmental findings in terms of what constitutes better knowledge structure. A small boy (4 1/2 years old) who's hobby was dinosaurs was examined. Through two tasks, they determined the structure of the child's knowledge by his verbal reports. The child demonstrated 20 well known and 20 lesser known dinosaur names. A semantic network representation was used as a framework within which to view the knowledge structure. This consisted of a number of nodes of knowledge clustered into meaningful groups with connections within and between groups by meaningful relations. A year later the child recalled 11 of the 20 dinosaurs of the well known group (i.e., the better structured memory set) but only 2 of the 20 he was less familiar with. The differential recall, retention, and clustering measures obtained on the two sets of knowledge were attributed to better known stimuli matching the structure of the child's knowledge base (i.e., the number of direct and indirect links among dinosaur concepts, the strengths of linkages, the particular intra- and inter-linkages) (Chi & Koeski, 1983). This study employing a within subject design which increased the ability to assume that capacity limitations remained relatively invariant under the two different stimulus conditions. Further, concept knowledge consisted of data generated by the subject rather than structure based on experimenter assumptions or theory a priori.

Gobbo and Chi (1986) investigated "how" the degree of structure predicts the degree of success of performance on memory and related tasks. In the domain of dinosaur knowledge, high knowledge and low knowledge children were given a production task (i.e., "say everyting you can about the word presented") and a sorting task (i.e., "sort the pictures of the dionosaurs and tell why"). Knowledge structure was based on protocol measures (i.e., the frequency of use of connecting words, the frequency of topics in relation to a given topic, and their rules for determining class membership). Of significance, was how this knowledge was used in learning new dinosaur concepts and in making decisions about familiar dinosaur concepts. Verbal reports were used to analyze the frequency with which new implicit information was infered and the frequency of semantic comparisons. The results indicated the expert's more structured and cohesive knowledge influenced differences in what was focused on during problem solving: novice children focused on the surface (explicit) features of concepts, whereas experts focused on more abstract or deep-level (implicit) concepts. As a result, expert children could facilitate their use and access of knowledge in a more sophisticated way. Overall, experts were able to infer implicit information about unknown dinosaurs, reason analogically in terms of comparing the similarity of dinosaurs and reason with the presence or absence of a feature to determine class membership.

Overall, knowledge base, once regarded to be an inherent deficite in children's information processing systems, is now considered a crucial dimension of development. Recent research demonstrates knowledge base has the ability to reduce well known developmental differences in information processing and can influence the success of performance on memory and related tasks regardless of age.

The Development of Expertise

Since much of one's knowledge base is domain specific, the study of experts may lead to an understanding of how knowledge is developed and how expertise is acquired. Ultimately, the changes that underly the development of expertise in general may also be similar to those that underlie age-related differences. Adult experts across domains are found to be similar in terms of: (a) knowledge structure, (b) processing of input information, and (c) approaches to solving problems.

Overall, the knowledge structure of experts when compared to novices exhibits: more concepts, more relations defining each concept, more relations interconnecting concepts, more robust relations for retrieving related concepts, and more procedures (i.e., decision rules) concerning how to perform in response to specific situations (e.g., Chase & Simon, 1973a,b; Chi, Feltovich, & Glaser, 1981; Chi & Glaser, 1980). Some discrepency has been noted in specific domains (i.e., clinical diagnosis) but this may be due to the nature of the domain investigated (Murphy & Wright, 1984).

The expert's knowledge structure is also linked to the processing of input information, that is, the ability to encode more rapidly and/or encode in larger units (e.g., Berliner, 1986; Chase & Simon, 1973a,b; Housner & Griffey, 1985; Lesgold, Feltovich , Glaser, & Wang, 1981; Shaveneveldt, Durso, Goldsmith, Breen, & Cooke, 1985). The expert's fast and accurate pattern recognition denoted in recall tests occurs only when the pattern recalled is a function of experience (e.g., a familiar chess pattern). This encoding ability indicates differences attributed to one's specific knowledge rather than superior memory capacity (Allard & Burnett, 1985). Many theorists have used Chase and Simon's (1973 a,b) 5-sec recall paradigm, attributing the results to expert's chunking skill across a variety of domains from music (Slaboda, 1979) to bridge (Charness, 1979). Other theorist propose, the processing of input information may not be due to deliberate strategies but to the automatic exercise of associative pathways in the knowledge base in some form of a "retrieval structure" (for a review see Chase & Ericcson, 1981).

Similarities are also denoted in the ways experts approach problem solving or focus on the problem to be solved (for reviews see Berliner, 1986; Thomas, French, & Humphries, 1986). Experts represent problems at more abstract levels making inferences about objects and events, whereas novices represent problems to be solved by surface features making inferences from literal views of objects and events. These findings are evident in physics (e.g., Chi, Feltovich, & Glaser, 1981; Simon & Simon, 1978), computer programming (e.g., Adelson, 1981, 1984; McKeithen, Reitman, Rueter, & Hirtle, 1981; Schneiderman, 1977), games (Charness, 1979; Reitman, 1976), and physicians (Patel & Groen, 1986).

The abstract representation of experts is exhibited in relation to their goal structure of the problem. One of many examples is found in expert and novice physicians clinical diagnosis. Patel and Groen (1986) found experts correct diagnosis of a case was due to their medical reasoning embedded in their knowledge structure, whereas novices diagnosis (usually inaccurate) was based on rules generated in the literal features of the case text. In some domains, verbal reports indicate details of these processes are hidden, as experts are unaware of their decision making process, that is, the details of how they did it (Adelson, 1984). However, this may vary according to the domain or methodology of the research.

Metacognitive activities or sport specific strategies (e.g., planning, monitoring outcomes) are also similar for experts. Berliner (1986) notes expert teachers are simlilar in their planning activities that take place prior to their encounter with the problem such as: an awareness of time (Hanninine, 1985), sensitivity to task demands (Housner & Griffey, 1985), and skillful alternative planning of possible occurences. Also, Chi and Glaser (1980) found novices were similar in their metacognitive activities as they questioned their solutions, errors, and goals of the problem.

One generalizable finding across all domains is that expertise is acquired over the years and with much practice. Overall, domain experts' structure of knowledge, encoding ability, and approach to problem solving allows: (a) faster and more accurate decisions, (b) quicker responses due to anticipation and probabilities, (c) ability to work at a higher level of problem solving, and (d) an increased ability to select an appropriate strategy.

In some domains (e.g., teaching) problems are noted when examining expertise such as setting criteria standards and which areas should denote knowledge expertise (e.g., subjects to be taught, and/ or classroom management skills). Also, increases in terms of task performance or problem solving ability may not always be the case as one progresses towards expertise. Patel and Groen (1986) found medical students out-performed interns in case diagnosis. That is, the interns had a tendency to overdiagnose patients. They caution, for a good theory of how one acquires expertise, researchers should add another group of intermediate performers in order to establish progression towards expertise.

The Development of Sport Expertise

The influence of knowledge base in highly structured goal-oriented sports may illustrate similar characteristics of expertise (e.g., faster and more accurate decisions) mentioned earlier. Sport performance requires not only a repetoire of motor skills but cognitive skills as well. Until recently, however, these cognitive skills were not examined as an important aspect of skilled performance. Researchers interested in children's (see, Thomas et al., 1986 for a review) and adult's (see Allard & Burnett, 1985) motor skill acquisition are now realizing the influence of previous experience in sport skill performance should be examined for practical as well as theoretical purposes.

Sport experts, as in other domains, exhibit an extensive semantic network of sport specific knowledge. Chiesi et al. (1979) and Spilich et al.(1979) investigated text processing of high and low knowledge adults in the domain of baseball. Although these studies did not investigate knowledge base in terms of actual sport performance, their results and others (e.g., Allard, Graham, & Paarsalu, 1980; Starkes & Deakin, 1984) support findings reviewed earlier in the verbal literature and add to our information about how knowledge base influences sport performance (for a review, see Thomas, French & Humphries, 1986).

A hierarchial knowledge structure of baseball was postulated by Chiesi et al. (1979) and Spilich et al. (1979) to consist of the games goal structure, the states and actions of the game, and information concerning the setting in which the game takes place. Findings were consistent with this type of structure as differences of high and low knowledge adults were found in terms of (a) knowledge of the goal structure, (b) knowledge of how the actions and the states relate to the goal structure and (c) the processing of the sequences of game actions. That is, high knowledge individuals organized information higher in the goal structure, and generated more possible game actions which were related to higher order goals. This approach to solving the problem at a higher level is similar to other domains where experts were more abstract in their problem solving. Also, high knowledge adults recalled larger chunks of information which were usually organized as a given sequence of actions. The processing of input information was speculated to be relative the goal structure of the game. Also, the experts were better at monitoring and detecting changes in game actions and states and relating these to the goal structure. Chiesi et al. (1979) and Spilich et al. (1979) speculate that in order to develop a high knowledge of a sport, an individual must first, understand the goal structure and be exposed to a large number of games. Further, he or she must learn to interpret the game actions in terms of the games goal structure which may require instruction.

Allard and Burnett (1985) examined basketball experts and novices picture sorting of play situations. A cluster analysis revealed the novices sorted on a surface level (i.e., on single skills and number of players), whereas experts sorted on a more abstract or deeper level (i.e., what the players were doing in terms of offense). Research in other sports, also indicates experts process input information differently for making predictions of the flight of an object and for making decisions within the context of offensive and defensive configurations (e.g., Bard & Fluery, 1976, 1981; Jones & Miles, 1978). Similar to other non-sport experts, adult field hockey players (Starkes & Deakin, 1980) and basketball players exhibited sensitivity only in regards to actual game structures or patterns (Allard, Graham, & Paarsula, 1980) occuring in the sport. However, Allard and Starkes (1980) found expert volleyball players were better, regardless of the presentation context, which may indicate this relation is sport specific. Further, they suggest that perceptual strategies may vary across sports as a function of the speed and complexity of the sport.

Within a sport specific domain, Thomas, et al. (1986) speculate that the role knowledge base development plays in sport performance is due to more effective and efficient response selection (i.e., in less time and with less information) within the context of a game situation. That is, increased performance of high knowledge players is due to access to more and better information reducing processing time and a greater ability to monitor changes in goal states and actions through sport specific strategies (Chiesi, et al., 1979; Spilich, et al., 1979).

Housner (1981), examined the relation between knowledge structure and cognitive processes of an expert and novice adult's badminton play. Overall, the expert exhibited more strategic concepts, more interconnections among concepts and more production systems (if-then statements) stored in memory. As a result, Housner (1981) proposed the expert's strategy for solving the badminton problem involved the "chunking" of pertinent information in order to make an appropriate strategic response. The novice had no reason to gather and chunk information due to his less strategic knowledge structure. Verbal reports, before, during, and on completion of play indicated the expert processed information regarding sequential probabilities and contingencies of the opponents play.

The trends of Housner's (1981) expert indicated findings similar to other domain experts. This investigation was significant in that it examined the influence of knowledge and how this knowledge influences the strategies employed. That is, the expert used a problem solving approach in which information was gathered regarding sequential probabilities and contengencies of the opponents play. The mode of processing this information was the chunking of crucial strategic events in memory.

French and Thomas (1987) were instrumental in not only examining the relation of sport knowledge developmentally, but in examining the relation of basketball knowledge and sport performance rather than the previous paradigms employing cognitive tasks. They found decision making ability (directed by the extent of specific content information) a crucial link in terms of expert and novice basketball players regardless of age. Also, across a season, cognitive skills rather than motor skills increased, as basketball players learned what to do at a more rapid pace than their skill to do it improved.

Thomas et al. (1986) predict experts in sport realize the importance of sport specific strategies to (a) monitor changes in goal states and actions, (b) plan for possible actions, and (c) predict game actions. Some of the strategies consist of using external memory aids, using natural pauses during the game to plan game tactics, and attending to environmental cues from the situation or past events to attach probabilities to possible outcomes.

Conclusions

Research by Lindberg (1980) and Chi (1978), as mentioned earlier, are correlational and their findings do not provide an explanation of how such differences arise. In order to link what is already known to the acquisition of new information, Ornstein and Naus (1984) feel research should examine the information available in the knowledge base together with the strategies employed. This interaction of the components of an information processing model may ultimately lead to a better understanding of how the changing knowledge base influence, simple and complex strategies, as well as more automatic memory processes.(e.g., Naus & Ornstein, 1983; Ornstein & Naus, 1984; Ornstein & Baker-Ward, 1983)

Across a variety of domains (e.g., teaching, sports, games), strategies such as chunking, monitoring, and input processing were influenced by the subject's content knowledge. Also, Ornstein and Naus (1984) in reviewing knowledge base mediation in adult research (e.g., Chi, 1978; Richman, Nida, & Pittman, 1976; Spilich et al., 1979) found memory performance represents a very complex interaction of knowledge about strategies and their implementation, knowledge of specific task requirements, and knowledge about particular topics. Ornstein and Naus (1984) speculate knowledge base influences memory performance in two different ways: by the operation of memory strategies, and in a direct fashion (i.e., automatic processes). These differences require future invesgations considering the conditions under which they occur and details of the mechanisms by which direct effects of knowledge base operate.

Gobbo and Chi (1986) and Housner (1981) have made significant contributions using paradigms that examine how knowledge influences the aquisition of newly presented material and how sport knowledge influences sport performance. Also, French and Thomas (1987) found the improvement with age and across a season within a specific sport was attributed to sport specific knowledge. These studies indicate the need for researchers to investigate further the relation between performance (e.g., skilled sport behavior) and knowledge base development (e.g., the development of the sport specific knowledge base).

Future domain specific investigations should consider: (a) the structure of knowledge base, (b) the use of procedures to identify mnemonic processes called into operation, (c) the differentiation between deliberate mnemonic processes and automatic non-deliberate processes, and (d) how these strategies and processes change with age-related developments in the contents and structure of knowledge base (Naus & Ornstein, 1983). It is clear from the present review that the role of knowledge acquisition in memory development is in a preliminary stage. Researchers are just beginning to examine the relation between knowledge base and performance (verbal or sport). If researchers can understand the role of cognition (i.e., the interaction of sport knowledge base and sport specific strategies employed to work with the sport knowledge base) in sport performance, they may be able to influence the development of this sport specific knowledge and ultimately enhance and ease the development of expertise in sport skills. Theoretically, understandings of the changes in the properties of information represented and how this information interacts with the formation of sport specific strategies used to generate the appropriate response may be increased.

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Appendix C

Permission and Experience Forms

Prior to the study participants were asked to obtain parental permission for inclusion in the study. A questionnaire form was also designed to exam the subjects history in terms of tennis experience which was used a one of the criteria for expertise grouping. A sample of each of these forms is presented on subsequent pages.

Dear Parent:

We are conducting a study on how children's sports skills change as they learn to play tennis. During camp, I will be watching the children play and evaluating their skills and game knowledge. This will involve some filming of matches, a paper and pencil test, and some measurements on their consistency and acurracy of the serve and groundstrokes. This is sponsored by the School of Health, Physical Education, Recreation and Dance at LSU. The Pelican Tennis Camp is not involved in the study, but Steve Carter and the staff are cooperating by letting us do it. Ratings of the children's abilities will be kept strictly confidential; if our findings are published, or presented at a professional meeting, average scores will be the only ones reported without the children's identification.

We would greatly appreciate your permission to include your child in our study.

Sue McPherson, Graduate Student 344-4908

Jerry Thomas, Professor, LSU, 388-2387,2034

Thanks so much for your cooperation!

My child ______________________, has my permission to participate.

Signature ________________________date__________

Phone # _________________ Call me if you have any questions.

Sue McPherson, 344-4908

Dear Parent:

We are conductinq a study on how children's sports skills change as they learn to play tennis. During lessons, I will be watching the children play and evaluating their skills and game knowledge. This will involve some filming of matches, a paper and pencil test, and some measurements on their consistency and acurracy of the serve and groundstrokes. This is sponsored by the School of Health, Physical Education, Recreation and Dance at LSU. BREC is not involved in the study, but Karen Toney and the staff are cooperating by letting us do it. Ratings of the children's abilities will be kept strictly confidential; if our findings are published, or presented at a professional meeting, average scores will be the only ones reported without the children's identification.

We would greatly appreciate your permission to include your child in our study.

Sue McPherson, Graduate Student 344-4908

Jerry Thomas, Professor, LSU, 388-2387,2034

Please sign the form below and your child may return the form to his instructor. I will get in touch with you and your child to schedule his filming either before or after his regularly scheduled lessons.

Thanks so much for your cooperation!

My child ______________________, has my permission to participate.

Signature _________________________date___________

Phone # __________________ Call me if you have any questions.

Sue McPherson, 344-4908

Name ______________________ Address ST. ______________

Date of Birth ______________________ City ______________

Phone # ______________________ ZIP ______________

Circle the answer that best describes you.

I practice tennis ____ times a week. 1, 2, 3, 4-7, sometimes

I play tennis ______ times a week. 1, 2, 3, 4-7, sometimes

I've had a total of ________ of tennis lessons.

a week

a month

a year

more than a year

I haven't had any

I've been playing tennis ____, 3 months, 6 months, 1 year,

2 years, 3 or more years

In my family ______________________ tennis.

I am the only one that plays

1 other member plays

2 other members play

3 or more other members play

List any programs (JR., City, School, Club, Camp) you have attended or play in.

PROGRAMS	HOW LONG	WHEN

List any tournaments you've played in.

TOURNAMENT	WHEN	DID YOU PLACE

List any tournaments you've played in.

TOURNAMENT WHEN DID YOU PLACE

Appendix D

The Knowledge Test

Knowledge Test

A 50-item multiple choice test to examine tennis knowledge was judged valid in content by 3 tennis expert, all nationally certified instructors with collegiate playing experience involved in coaching youth tennis. Also, a certified elementary educator deemed the test valid in language content for these age groups. These four experts critiqued the test before it was piloted in terms of terminology, balance, and coverage of knowledge.

The written test was administered to 31 expert and novice male tennis players ages 8-13 attending the first camp session. A KR-20 estimate indicated internal consistency of .79. The median of the index of difficulty was .58. Forty-eight of the 50 items (98%) had an index of difficulty between .35 and .90. Forty of the 50 items (80%) had an index fo discrimination of .20 and greater (range .20 to .80) with the remaining 10 receiving .10 or greater an an index of discrimination. These measurements are presented in the subsequent Table 16.

The test was also shown to discriminate between expert and novice tennis players regardless of age. Construct validity (known group difference method) is presented in Table 18. The mean for novices was 62% correct (S=11%) and the mean for experts was 74% correct (S=9%). The percent variance accounted for by the group difference was 25%.

The original test was revised for questions receiving an index of discrimination below .20. The revised knowledge test was administered to 21 male tennis players ages 8-13 attending the second camp session. The median index of difficulty was .50. Forty-eight of the 50 items (96%) had an index of difficulty greater than .23. The mean of the index of discriminatiion was .31. Forty of the 50 items (80%) had an index of discrimination greater than .20. Measurements for each question are presented in Table 17.

Overall, these results indicate that the knowledge test is a reliable and valid measure of tennis knowledge for males ages 8-13 years-old. The means and standard deviations are presented in Table 19.

Table 16. Index of difficulty and index of discrimination for the first knowledge test.

Item	Difficulty	Discrimin.	Item	Difficulty	Discrimin.
1.	.84	.20	26.	.74	.70
2.	.58	.20	27.	.48	.30
3.	.81	.10	28.	.87	.30
4.	.61	.20	29.	.84	.74
5.	.45	.50	30.	.74	.10
6.	.81	.30	31.	.97	.10
7.	.87	.30	32.	.97	.10
8.	.90	.20	33.	.48	.40
9.	.52	.40	34.	.71	.10
10.	.52	.40	35.	.35	.30
11.	.64	.70	36.	.84	.40
12.	.58	.40	37.	.48	.70
13.	.52	.30	38.	.42	.50
14.	.84	.30	39.	.48	.10
15.	.90	.10	40.	.52	.70
16.	.84	.20	41.	.52	.70
17.	.45	.20	42.	.45	.40
18.	.42	.30	43.	.68	.10
19.	.71	.40	44.	.48	.20
20.	.35	.40	45.	.58	.40
21.	.58	.10	46.	.58	.30
22.	.65	.80	47.	.61	.60
23.	.87	.20	48.	.61	.50
24.	.48	.40	49.	.68	.40
25.	.19	.10	50.	.39	.51

Table 17. Index of difficulty and index of discrimination for the second knowledge test.

Item	Difficulty	Discrimin.	Item	Difficulty	Discrimin.
1.	.29	.20	26.	.81	.50
2.	.33	.24	27.	.67	.67
3.	.81	.33	28.	.81	.50
4.	.76	.67	29.	.90	.17
5.	.57	.52	30.	.95	.17
6.	.38	.54	31.	.86	.02
7.	.71	.36	32.	.28	.47
8.	.10	.23	33.	.57	.24
9.	.57	.38	34.	.81	.36
10.	.52	.21	35.	.71	.05
11.	.67	.27	36.	.90	.02
12.	.62	.21	37.	.48	.20
13.	.48	.07	38.	.48	.23
14.	.67	.38	39.	.76	.36
15.	.24	.23	40.	.57	.55
16.	.14	.02	41.	.57	.17
17.	.24	.26	42.	.33	.17
18.	.38	.24	43.	.19	.36
19.	.67	.52	44.	.62	.69
20.	.48	.38	45.	.62	.26
21.	.67	.21	46.	.62	.07
22.	.62	.52	47.	.67	.83
23.	.86	.12	48.	.67	.21
24.	.62	.24	49.	.86	.17
25.	.67	.36	50.	.33	.40

Table 18. ANOVA table for the written test for age and expertise levels.

Source	df	SS	MS	F
Age Level	1	1.38	1.38	0.13
Expertise Level	1	0.11	0.11	10.44**
Interaction	1	2.01	2.01	0.18
Error	27	0.30	0.01	
Total	30	12.67		

**p<.01

Table 19. Means and standard deviations for the percentage of correct responses on the tennis knowledge test by age and expertise level.

	Novices			Experts		
	M	S	N	M	S	N
8-10 years	.61	.08	7	.73	.05	5
11-13 years	.62	.13	10	.75	.11	9

TENNIS KNOWLEDGE TEST

1. In scoring, which is not one of the following points?
   a. 15
   b. 40
   c. love
   d. 30
   e. game

2. In a 9 point tiebreaker players change ends after
   a. 1 point
   b. 2 points
   c. 3 points
   d. 4 points

3. The best grip for a good player when volleying is
   a. the eastern or handshake
   b. the western
   c. the continental
   d. the choke

4. To receive a serve it is best for a good player to stand;
   a. deep behind the baseline in the backcourt area halfway between the singles sideline and center service line
   b. close to the center mark behind the baseline the alley when receiving on the left
   c. near the baseline and singles sideline

5. Which ball is not a let in tennis?
   a. a ball that is unsuccessfully returned because of outside interference
   b. a ball that is served before the receiver is ready
   c. a ball that hits the net on serve but bounces in the service court to which it was directed
   d. a ball that hits the net on serve but bounces in the alley

6. Most groundstrokes should be hit
   a. down the line
   b. in the middle
   c. cross court
   d. none of these

7. You change ends of the court when the game score adds up to
   a. an even number
   b. an odd number
   c. 3, 6, 9, 12, etc.

8. After a tiebreaker
   a. players change ends of the court where the tiebreaker was completed
   b. players stay on the ends of the court where the tiebreaker was completed
   c. the players spin to see if they change ends

9. The lob should be used
   a. to go over a player's head at the net
   b. to recover your position
   c. to change pace in a long rally
   d. all of the above

10. The height of the net at the center of the court is
   a. 2 1/2 feet
   b. 3 feet
   c. 3 1/2 feet

11. Which serve will have more power?
   a. spin
   b. slice
   c. flat
   d. none of these

12. What is the score at the beginning of each game?
   a. 0-0
   b. Love-all
   c. both a and b

13. When moving across court to play a ball, you should
   a. slow down to stroke the ball, turn, and move in a side-to the net position
   b. stroke the ball while moving
   c. attempt to stop running, then stroke the ball
   d. both a and c

14. What is the number of lets a server may have?
   a. one
   b. two
   c. three
   d. there is no limit

15. Which of the following strokes will involve movement of the wrist
   a. smash
   b. forehand
   c. backhand
   d. volley
   e. both a and d

16. When you are standing to the right of the center mark and hit cross

   court it is best to
   a. move to the left side of the center mark
   b. remain in the area to the right side of the center mark
   c. return to the center mark

17. The score will always be odd when serving to the
   a. left service court
   b. right service court
   c. advantage court
   d. both a and c

18. It is legal for you to follow through over the net
    a. before stroking the ball on your side of the net
    b. after stroking the ball on your side of the net
    c. it is never legal to follow through over the net

19. When playing a baseline game you should stand
    a. on the baseline
    b. between the baseline and service line
    c. three feet behind the baseline

20. After stroking a ball that lands inside the service court area you should
    a. run to the middle of the court
    b. stay at the net
    c. run back to the baseline
    d. both a and c

21. When serving in singles you should stand
    a. close to the singles sideline
    b. between the singles sideline and center mark
    c. close to the center mark

22. In playing singles tennis which is more important?
    a. shots that barely clear the net
    b. keeping the ball deep
    c. keeping the ball in the middle
    d. none of these

23. When the score is tied at 40-40 or 40-all it is
    a. let
    b. game
    c. deuce
    d. ad-out

24. A foot fault is when the server's foot touches the baseline or court
    a. while preparing to serve
    b. after the ball is hit
    c. before the ball is hit
    d. both a and b

25. A tiebreaker is used to shorten a set when the game score reaches
    a. 6-5
    b. 5-5
    c. 6-6
    d. 5 all
    e. both b and d

26. A good tennis player should try to
    a. keep the ball in play
    b. keep the ball deep
    c. attack the short ball
    d. all of these

27. The receiver must stand
    a. outside the service court
    b. behind the baseline
    c. anywhere he or she pleases

28. When serving you should first work on
    a. getting the ball in the service court every time
    b. placing the ball deep in both corners of the service court
    c. power and spin

29. The score is 4-2, a total of 6 games;
    a. play continues
    b. the set is over
    c. the match is over
    d. a tiebreaker is played

30. On return of service, the receiver must hit the ball on
    a. one bounce
    b. no bounce
    c. none of these

31. You should work on ______ last when practicing groundstrokes
    a. direction
    b. placement
    c. power

32. When using topspin, you should hit the ball
    a. above its center of gravity
    b. below its center of gravity
    c. at the center of gravity

33. A poor grip for the serve is
    a. western
    b. eastern
    c. continental

34. You should prepare to return the ball
    a. when the ball bounces on your side of the court
    b. just after the ball leaves your opponents racket
    c. as the ball reaches the net
    d. when you stroke the ball

35. Most approach shots should be hit
    a. cross court
    b. down the line
    c. to the center of the court
    d. none of these

36. In calling the score, the player's score mentioned first is
    a. the server
    b. the reciever
    c. the server or receiver

37. When getting to a wide groundstroke it is best to move
    a. along the baseline
    b. back behind the baseline
    c. in a diagonal to the ball

38. A slice will
    a. cause the ball to spin in the opposite direction
    b. cause the ball to not bounce very high
    c. give your opponent less time to get to the ball
    d. all of these

39. After you hit an approach shot you should
    a. stand behind the service line in the middle of the court
    b. stand close to the singles sideline
    c. follow the path of your ball to the net

40. The harder you hit the ball
    a. the less time you will have to get ready for the next shot
    b. the faster the ball will come back to you
    c. the more likely you will make an error
    d. all of these

41. Offensively, you can force your oponent to run all over the court by
    a. hitting groundstroke drives to the corners
    b. hitting dropshots when they are behind the baseline
    c. hit lobs when they are at the net
    d. both a and c
    e. all of these

42. A deep cross court shot is considered safer than down the line because
    a. it carries over the longest distance of the court
    b. it carries over the lowest part of the net
    c. it carries over the highest part of the net
    d. both a and b

43. If you lob to your opponent, it is best to direct it
    a. down the line
    b. to the forehand side
    c. to the backhand side
    d. crosscourt

44. A good offensive move is
    a. to clear the net with plenty of height
    b. to get your first serve in
    c. to hit cross court
    d. all of these

45. You will pull your opponent wide if you return deep
    a. down the line
    b. cross court
    c. to the middle

46. When driving a ball deep to the corners you should aim
    a. for the baseline
    b. just past the baseline
    c. well inside the baseline

47. A good tennis player selects shots based on
    a. the opponent's position
    b. the ball's position
    c. his or her position
    d. all of these

48. If you have been drawn wide behind the baseline you should
    a. smash
    b. lob
    c. groundstroke

49. Which shot is best to use against a short lob?
    a. dropshot
    b. smash
    c. topspin backhand
    d. lob

50. If your opponent has a closed stance he will probably hit
    a. a slice
    b. straight ahead
    c. crosscourt
    d. a lob

Appendix E

The Serve Skill Test and Groundstroke Skill Test

Skill Tests

For skill evaluation, a groundstroke and serve skill test were constructed by modifying a variety of accepted skill tests (Avery, Richardson, & Jackson, 1979; DiGennaro, 1969; Gruetter & Davis, 1985; Hewitt, 1966; Purcell, 1981). Groundstroke skill was measured by the tester (the experimenter) delivering a total of 24 balls to each player who attempted to stroke 10 froehand and 10 backhand groundstrokes which were scored on the bases of the target area hit. Serve skill consisted of each player serving a total of 24 balls into target areas for both the right and left service court. All trials consisted of 1 practice and 5 scored strokes of serves.

As indicated in Figure 1, two target areas were drawn for each half of a regulation singles tennis court with each corner of the singles sideline and baseline consisting of a 4' x 4' chalked area (3 point zones). Out from these two areas, 4' x 4' scoring areas were drawn (2 point zones) with the remainder of each court area from the center of the center stripe to the back service line consisting of 1 point zones. The scoring zones consisted of each service court area divided in half 6'9" (2.058m) by 21' (6.401m) designating the forehand and backhand serve zone for the right and left service courts. The deepest area was designated by a 4' by 6'9" chalked area (3 point zone), and 4' by 6'9" chalked area (2 point zone), and finally, the remainder of the zone divided midway between the side and center service line. (see Figure 1)

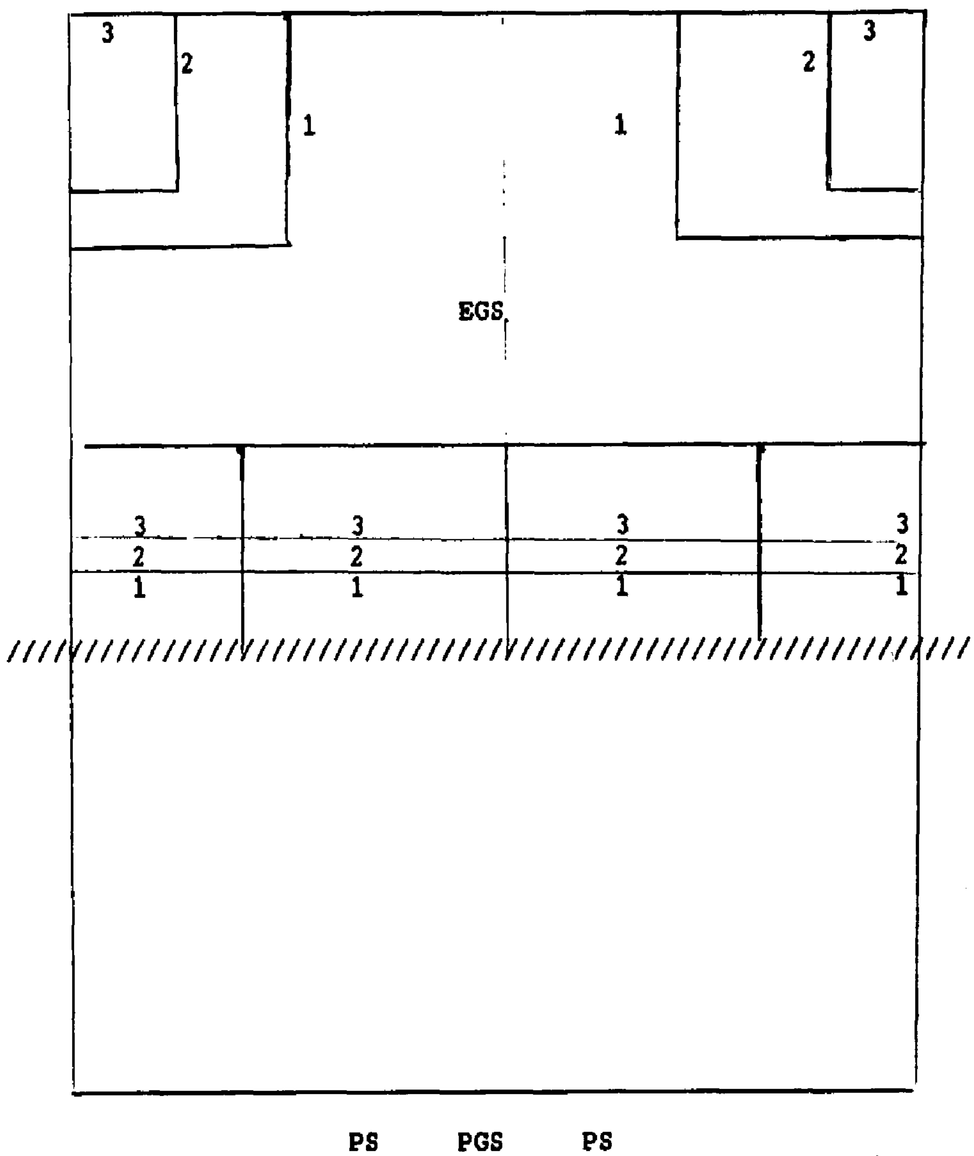
Scoring of the forehand and backhand groundstrokes consisted of number zones marked on the lines for their respective spaces-3, 2, and 1 with the higher score nearer the baseline. The total possible points for groundstrokes (i.e., both forehand and backhand) was 60 points.

Groundstrokes that hit the net and went into the proper scoring area received the score of the area. Groundstrokes that went into the net or out of the proper court received a zero. Groundstrokes that landed on lines of the court were good. Also, groundstrokes that landed on the score lines received the higher score. Only groundstrokes were scored. Intentional or unintentional lobs (judged by the experimenter) were retested.

Serve skill was measured using procedures similar to the groundstroke skill test in which the serve was scored on the basis of the target area hit. In performing the service test, the tester handed the ball to the subject who assumed his service stance at a marked service position. The server first served into the right service court consisting of two target areas representing a forehand and backhand service zone (see Figure 1). Subjects were reminded prior to testing to strive for accuracy rather than speed.

Figure 1

Court layout for the groundstroke and serve skill tests.



EGS = experimeter position on groundstroke
PGS = player position on groundstroke
PS = player position on serve

Code Sheet for the Groundstroke and Serve Skill Test

Name ______________ Group ___________ Date_____

ID __________

GROUNDSTROKE

FH

DL____ _____ _____ ____ ____ CC___ _____ ______ _____ ____

BH

DL____ _____ _____ ____ ____ CC___ _____ ______ _____ ____

Total _____

SERVE

EVEN

W__ ___ ____ ____ __DL___ ____ _____ _____ _____

ODD

W__ ___ ____ ____ __DL___ ____ _____ _____ _____

Total______

Reliability of the Skill Tests

The reliability and validity of the skill tests was established by a test-retest procedure and expert judgement. The skill tests were deemed valid by 4 tennis experts. The skill tests were administered twice to 8-10 year old (n=14) and 11-13 year old (n=20) male tennis players during the first camp session. Skill testing was administered by the experimenter (an expert) on a regulation tennis court to each individual in small groups of 3 to 4 subjects. Total scores for the 20 groundstroke trials and 20 serve trials were used in the analyses. The groundstroke skill test was administered prior to the serve skill test with ample practice and rest periods for each test.

The scores for each skill test were analyzed separately for each age level in a 2 x 2 (subject x day of testing) ANOVA. Intraclass correlation coeficients for the serve and groundstroke skill tests were .91 and .72 for the younger age group, and .87 and .88 for the older age group. Table 20 indicates the means and standard deviations for each age group for the serve and groundstroke skill test trials. The skill tests were also found to discriminate between experts and novices regardless of age in a 2 x 2 ANOVA (age x level of expertise) for the final scores of each skill test. The novice group consisted of 7 8-10 year-olds and 11 11-13 year-olds. The expert group consisted of 7 8-10 year-olds and 9 11-13 year-olds. Experts were found significantly different from novices in the groundstroke skill test, $F(1,30)= 17.55$, $p<.01$, w2 = 47%, with no significant age, $F(1,30)= 3.60$, $p>.05$, or interaction effects, $F(1,30)= 0.11$, $p>.05$. Similar results were indicated for the serve skill test as experts were significantly different from novices, $F(1,30)= 18.71$, $p<.01$,w2 = 53%, with no significant age, $\underline{F}(1,30) = 0.16$, $\underline{p} > .05$, or interaction effect, $\underline{F}(1,30) = 0.48$, $\underline{p} > .05$. The means and standard deviations for each group for the groundstroke and serve skill test are presented in Table 21.

Table 20
Means and standard deviations for each age group for the serve and groundstroke skill test trials.

		Groundstroke		Serve	
		Day		Day	
		1	2	1	2
Age					
8-10 (n=14)	M	11.2	12.6	14.2	14.3
	S	3.8	4.1	4.3	4.1
11-13 (n=20)	M	11.4	12.4	14.2	14.6
	S	5.6	5.1	5.6	6.5

Table 21

Means and standard deviations for each age group for the groundstroke skill test by expertise level.

	Novices			Experts		
	M	SD	N	M	SD	N
8-10 Year Olds						
Ground stroke	10.0	2.7	7	15.1	3.7	7
Serve	11.3	2.2	7	17.3	3.4	7
11-13 Year Olds						
Groundstroke	9.6	4.3	9	15.7	4.1	11
Serve	10.3	4.0	9	19.1	7.2	11

Table 22. ANOVA table for the serve and groundstroke test for 8-10 year- olds.

Serve

Source	df	SS	MS	F
Subjects	13	425.75	32.75	10.26**
Day of Testing	1	0.04	0.04	0.01
Error	13	41.46	3.19	
Total	27	467.25		

$R = \frac{MSsubjects - MSwithin}{Mssubjects}$ where $MSwithin = \frac{SSday + SSerror}{dfday + dferror}$

$MSwithin = \frac{.04 + 41.46}{1 + 13} = \frac{41.50}{14} = 2.96$

$R = \frac{32.75 - 2.96}{32.75} = .91$

Groundstroke

Source	df	SS	MS	F
Subjects	13	324.18	24.94	3.87**
Day of Testing	1	12.89	12.89	2.00
Error	13	83.61	6.43	
Total	27	420.68		

$R = \frac{MSsubjects - MSwithin}{Mssubjects}$ where $MSwithin = \frac{SSday + SSerror}{dfday + dferror}$

$MSwithin = \frac{12.89 + 83.61}{1 + 13} = \frac{96.50}{14} = 6.89$

$R = \frac{24.94 - 6.89}{24.94} = .72$

Table 23. ANOVA table for the serve and groundstroke test for 11-13 year-olds.

Serve

Source	df	SS	MS	F
Subjects	19	1327.1	69.85	7.52**
Day of Testing	1	1.6	1.6	.17
Error	19	176.4	9.28	
Total	39	1505.1		

$$R = \frac{MSsubjects - MSwithin}{Mssubjects} \qquad \text{where } MSwithin = \frac{SSday + SSerror}{dfday + dferror}$$

$$MSwithin = \frac{1.60 + 176.4}{1 + 19} = \frac{177}{20} = 8.8$$

$$R = \frac{69.85 - 8.8}{69.85} = .87$$

Groundstroke

Source	df	SS	MS	F
Subjects	19	701.85	36.94	8.83**
Day of Testing	1	9.02	9.02	2.16
Error	19	79.48	4.18	
Total	39	790.38		

$$R = \frac{MSsubjects - MSwithin}{Mssubjects} \qquad \text{where } MSwithin = \frac{SSday + SSerror}{dfday + dferror}$$

$$MSwithin = \frac{9.0 + 79.46}{1 + 19} = \frac{88.5}{14} = 4.43$$

$$R = \frac{36.94 - 4.43}{36.94} = .88$$

Table 24. ANOVA table for the second day scores for the serve and groundstroke skill tests by age and expertise.

SERVE

Source	df	SS	MS	F
Age Level	1	3.78	3.78	.17
Expertise level	1	418.85	418.85	18.72**
Interaction	1	10.78	10.78	.48
Error	30	671.38	22 .38	
Total	33	7373.42		

GROUNDSTROKE

Source	df	SS	MS	F
Age Level	1	.05	.05	3.61
Expertise level	1	255.96	255.96	17.56**
Interaction	1	1.61	1.61	.11
Error	30	437.40	14.58	
Total	33	5336.8		

**$p<.01$

Appendix F

Coding of Game Performance

Coding Of Game Performance

An observational instrument was designed to record the components of performance (i.e., control, decision, and execution) of children during singles tennis play. The serve during game play was coded for decision and execution while game play following the serve was coded for control, decision, and execution. Decision rules were developed for each category by 3 experts (see Table 4 in the text).

Code sheets

The performance of each subject was coded using the guidelines. Behaviors of each individual during the 4 games were recorded on a code sheet for all 4 games. A sample code sheet is presented on the following page. The running score was also coded.

Code Sheet For Game Performance
Name ____________ Group ___________ Date _____________

SERVE 1ST

2ND

DEC (0-1)

poor/good

EXEC (0-4)

net,out,IP,F

CON(0-1)FH

yes/no BH
DEC(0-1)
B poor/good

A ReturS

C GrounS

K Lobs

C Passng

Dropsh

N Apprch

E Volley

T HalfVo

Smash

EXECUTION

(0-3)

unforced/forc

inplay forcing

RunningPOINTS

Reliability of the Coding Instrument

Four experts and 4 novices were videotaped playing 6 tennis games within two age levels (10-11 and 12-13) participating in a junior tennis program. Interrater reliability was established by two experts obseving 4 of the 6 games with each player serving and receiving serve twice. Four players were selected randomly from each experience and age level and coded on each category of the observational instrument for the serve and and game play following the serve. The behaviors coded were collapsed across all 4 games for each individual. Reliability was estimated by # of agreements/(# of agreements + disagreements) x 100 = %. Intrarater reliability was estimated by an expert coding and re-coding of all 8 players on separate occasions using the same procedures indicated in the inter-rater reliability condition.

Overall, intrarater reliability estimates (N=8) for the serve were .94 for decision and .88 for execution. During game play reliability was .99 for control, .87 for decision and .92 for execution. Likewise, interrater reliability estimates (N=4) for the serve were .99 for decision and .98 for execution, while 1.00 for control, .98 for decision and .99 for execution were denoted during game play. The coding instrument was considered reliable for all categories as interrater reliability estimates ranged from .94 to 1.00 while intrarater reliability estimates ranged from .82 to 1.00.

Game play was videotaped without spectators by the experimenter for all subjects. The filming was done from off court. Subjects were familiarized with filming prior to the actual taping used for the experiment. All games were videotaped using a panasonic video recorder (model NV-8200) and a panasonic color video camera (model WV-39900B) sound was also recorded. All players were told they were going to play a set of tennis although filming ended after 6 games were completed. Players went through their traditional match warm-up until both players agreed they were ready. The only exception to regulation play was elimination of changing sides after every first and odd game (for recording purposes). Regular scoring was used. For analysis, coding was done without the coders knowledge of the players expertise level or age.

Table 25

Intrarater reliability for 8 subjects - 2 coding sessions.

Categories	Subject 1	2	3	4	5	6	7	8
Serve								
Decision	1.00	1.00	1.00	1.00	.93	.85	.89	.83
Execution	.94	.88	.82	.86	1.00	.85	.85	.83
Game Play								
Control	1.00	1.00	1.00	1.00	1.00	1.00	.98	1.00
Decision	.93	.94	.83	.91	.85	.83	.85	.83
Execution	.93	.88	.92	.97	.91	.96	.94	.83

Table 26

Interrater reliability for 4 subjects - 2 coders.

Categories	Subject 1	2	3	4
Serve				
Decision	1.00	1.00	.97	.95
Execution	1.00	1.00	.97	.95
Game Play				
Control	1.00	1.00	1.00	1.00
Decision	1.00	1.00	.95	.98
Execution	1.00	1.00	1.00	.94

Appendix G

Coding of Verbal Interviews

Verbal Interviews

Verbal reports were used to assess what the performer basis his decisions on during the game. Two types of interviews will be employed: a situation interview to assess current status of tennis knowledge and a point interview to assess how this knowledge was employed during game play. Most researchers agree that verbal reports are accurate indicators of how an individual approaches or represents the problem to be solved (e.g., Bainbridge, 1979; Byrne, 1983; Ericsson & Simon, 1980). Matthews, Buss, and Stanley (1985) suggest two conditions are important in obtaining accurate verbal reports: (a)subjects should be questioned in a neutral way to avoid biasing responses, and (b) subjects should be questioned while the experiment is in progress (e.g., every 4th trial) to prevent distortion as to what they thought about during performance of the task. Also, as Bainbridge (1979) notes in a review of verbal reports, during an experiment there may be more than one optimal method for obtaining verbal responses. That is, the method used will depend on what the researcher is seeking.

Extensive pilot work was conducted with tennis players of varying age and expertise participating in the local junior program mentioned earlier. Modifications were made to ensure obtaining verbal reports during the test conditions were as condusive as possible to actual game play. Problems during pilot work were discovered in terms of: the child's understanding of the question, the ease and quickness of reponding (e.g., the location of the microphones), and the ability to remember the question being asked. Changes were made in the number of questions asked. Originally, one question examining past performance and a second question examining future performance were employed. However, players confused both questions and required too much time to answer, disrupting the natural pause occuring between points. As a result, only one question (i.e., the main question of interest) regarding the individuals decisions made during the past performance was used. Also, players during the actual testing were not allowed to pick up tennis balls prior to answering the question, as they tended to forget (during pilot testing) what they were thinking about. The question was also placed on the ground in front of the microphone to cue the player each time prior to responding. The situation interview was also examined during pilot work in terms of clarity of the diagrams and questions being asked. Each question was printed and stated verbally to each individual. The phrase "anything else" was found to elicite more answers and was used during actual testing. The wording of the questions were also phrased to prevent biasing the subjects towards a response (e.g., the word "strategy" was not used). Overall, Matthews et al. (1985) suggestions, together with the pilot work provided guidelines in constructing the test procedures.

The situation interview consisted of three categores of open-ended questions indicated in Phase 2 of the text. The question and administration of the point interview was also provided in Phase 2 of the text. Verbal reports collected between points were coded for each individual in a manner similar to the situation interview with the addition of agreements or disagreements in terms of what they intended to do (action(s) selected) and their ability to execution the action.

The situation interview was be administered, following all other testing, by the experimenter to each subject individually. The responses of each subject were recorded on cassett tape for coding purposes.

The point interview was administered to all subjects during game play following each point during 4 games of a tennis set. The point interview was administered during the videotaping of game play in Phase 1. Each subject was instructed separately (at the end of his respective court) prior to filming. The responses of both subjects were gathered upon each subjects arrival to his microphone area located beyond the baseline of the designated court(i.e.,in most cases, simultaneously) between each point. Responses were recorded on cassett and VHS tapes.

Coding Guidelines

Total Number of Different and Frequency Rate of Concepts:

Underline the unit of information, above the unit initial the appropriate category (i.e., SC, AC, GC) Repititions such as sentence clarification or elaboration were not coded twice.

Example: Condition Concept- His strength 11 4 total, 2 diff.

His weakness 11

Concept quality: Each concept will be coded according to the quality of the concept in the context of the interview situation or point situation.

Decision Rules

Condition Concept: inappropriate strategy 0

appropriate but weak (regarding only himself) 1

appropriate and forceful(1 forceful quality) 2

approriate and very forceful(2> forc qual.) 3

Action Concept: inapproriate action 0

approriate but weak (no forceful qual., only execution mentioned) 1

appropriate and forceful (1 forceful qual.) 2

approriate and very forceful (2> forceful qual.) 3

Goal Concept: skill and himself (execution, getting it in, keeping the ball in play) 0

himself and opponent (keeping the ball away, preventing opponents aggressive shots) 1

winning the point, game, match 2

Concept connections: Any word or phrase used to connect concepts will be circled. The total number of connections will be recorded for each individual. Only words or phrases between concepts were recorded.
Concept units: Concepts(s) will be coded regarding single, double, or triple units and categorized according to goals, actions, or strategies.
Others: will include statements that were made regarding a literal account of the events that occured (L), reactive or emotional statements (R), not thinking or non sport related statements (NL), and an abstract statement regarding the need to concentrate on the game (C).statements

Also for POINT INTERVIEW:

AGREE/DISAGREE

Agreements and disagreements verbalized in terms of what the player decided to do and his ability to carry out (execute) this decision.

Sample Code Sheet for the Point or Situation Interview

Name ____________ ID ________ P or S Date ____________

CONDITION CONCEPTS	ACTION CONCEPTS	GOAL CONCEPTS
His Strength	Serve	Keeping the
Weakness		ball away
Position	Return of Serve	
Prior Shot		Preventing
	Groundstrokes	aggresive
His Opponent's		shots
Strength	Lobs	
Weakness		Winning the
Position	Passing Shots	point
Prior Shot		
	Drop Shots	
Shot Type	Approach Shots	Executing
		the skill
Service Type		
	Volley	Getting the
Position Type		ball in
Forcing	Smash	
Central		Keeping the
Game Status	Position Moves	ball in play
TOTAL S	A	G
DIFF S	A	G
QUAL. S	A	G

UNITS S A G SA SG AG SAG

CONNEC.

OTHERS L R NT C

AGREE

DISAGREE

Reliability of the Verbal Coding Instrument

Performance reliability

Performance reliability on 8 subjects were obtained during the pilot work. The subjects were filmed twice (i.e., with and without verbal reports) playing 6 games each filming. Four experts and 4 novices were coded on the components of performance during each filming. The scores for each component of performance for serve and game play were analyzed separately in a 2 x 2 (Expertise x Filming) ANOVA with repeated measures on filming. A reliability estimate for each dependent measure (i.e., decision and execution) was obtained through intraclass correlation and were .99 in all analyses for the serve and game play.

Coding reliability

Inter-rater reliability was conducted for the situation interview and point interview in order to determine the consistency in identifying the same number of behaviors and in judging the quality of these behaviors. Interrater reliabilty of the situation interview and the point interview was determined by 2 experts classifying responses of 10 of the 40 subjects selected randomly (5 subjects each for the situation and point interview). Each category of the verbal coding instrument (i.e., total concepts, different concepts, quality concepts, and unit formation). Reliability was estimated by # of agreements/(# of agreements + disagreements) x 100 = % for each category. The same procedures outlined in experment one were followed. Intrarater reliability was conducted on 10 subjects (5 for the situation and 5 for the point interviews) coded on separate occasions using the same procedures indicated in the interrater reliability condition. The coding instrument was considered reliable for all categories a inter-rater reliability ranged from .93 to 1.00 while intrarater reliability was 1.00 for all categories.

Table 27. ANOVA table for performance reliability - 8 subjects by 2 (voice no-voice) trials for the serve category of the coding instrument.

Serve - strong decisions

Source	df	SS	MS	F
Subjects	7	13804	1972	600.17**
Voice/noVoice	1	16	16	4.87
Error	7	23	3.29	
Total	15	13843		

$R = \frac{MSsubjects - MSwithin}{Mssubjects}$ where $MSwithin = \frac{SSday + SSerror}{dfday + dferror}$

$MSwithin = \frac{16 + 23}{1 + 7} = 4.88$

$R = \frac{1972 - 4.88}{1972} = .99$

Serve - forceful executions

Source	df	SS	MS	F
Subjects	7	9625.44	1375.06	264.16**
Voice/noVoice	1	18.01	18.01	3.47
Error	7	36.44	5.21	
Total	15	9679.94		

$R = \frac{MSsubjects - MSwithin}{Mssubjects}$ where $MSwithin = \frac{SSday + SSerror}{dfday + dferror}$

$MSwithin = \frac{18.01 + 36.44}{1 + 7} = 6.81$

$R = \frac{1375.06 - 6.81}{1375.06} = .99$

Table 28. ANOVA table for performance reliability - 8 subjects by 2 (voice no-voice) trials for the game play category of the coding instrument.

Game Play - strong decisions

Source	df	SS	MS	F
Subjects	7	6663.75	951.96	145.66**
Voice/noVoice	1	2.25	2.25	.34
Error	7	45.75	6.54	
Total	15	6711.75		

$R = \frac{MSsubjects - MSwithin}{Mssubjects}$ where $MSwithin = \frac{SSday + SSerror}{dfday + dferror}$

$MSwithin = \frac{2.25 + 45.75}{1 + 7} = 5.97$

$R = \frac{951.96 - 5.97}{951.96} = .99$

Game Play - forceful executions

Source	df	SS	MS	F
Subjects	7	10279.75	1468.53	411.19**
Voice/noVoice	1	1.00	1.00	0.28
Error	7	25	3.57	
Total	15	10305.75		

$R = \frac{MSsubjects - MSwithin}{Mssubjects}$ where $MSwithin = \frac{SSday + SSerror}{dfday + dferror}$

$MSwithin = \frac{1 + 26}{1 + 7} = 3.25$

$R = \frac{1468.54 - 3.25}{1468.54} = .99$

Table 29.

Intercoder reliability for the situaiton interview, 5 subjects - 2 coders.

Categories		Subject				
		1	2	3	4	5
Total	s	1.00	1.00	1.00	.93	1.00
	a	1.00	1.00	1.00	1.00	1.00
	g	1.00	1.00	1.00	1.00	1.00
Diff	s	1.00	1.00	1.00	1.00	1.00
	a	1.00	1.00	1.00	.93	1.00
	g	1.00	1.00	1.00	1.00	1.00
Qual	s	1.00	1.00	1.00	1.00	1.00
	a	1.00	1.00	1.00	1.00	1.00
	g	1.00	1.00	1.00	.93	1.00
Units						
	sing	1.00	1.00	1.00	1.00	1.00
	dobl	1.00	1.00	1.00	1.00	1.00
	trpl	1.00	1.00	1.00	1.00	1.00

Table 30.

Intercoder reliability for the point interview, 5 subjects - 2 coders.

Categories		Subject				
		1	2	3	4	5
Total	s	1.00	1.00	1.00	1.00	1.00
	a	1.00	1.00	1.00	1.00	1.00
	g	1.00	1.00	1.00	1.00	1.00
Diff	s	1.00	1.00	1.00	1.00	1.00
	a	1.00	1.00	1.00	1.00	1.00
	g	1.00	1.00	1.00	1.00	1.00
Qual	s	1.00	1.00	1.00	1.00	1.00
	a	1.00	1.00	1.00	1.00	1.00
	g	1.00	1.00	1.00	1.00	1.00
Units						
sing		1.00	1.00	1.00	1.00	1.00
dobl		1.00	1.00	1.00	1.00	1.00
trpl		1.00	1.00	1.00	1.00	1.00

Appendix G References

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Appendix H

Additional Tables for Phase 1

Table 31. Ratios for the number of opportunities to respond by expertise levels during the serve and gameplay.

		Serve	Game Play
Games[a]	Expert	2	5.9
	Novice	1	1
Point[b]	Expert	1.6	4.8
	Novice	1	1

a the total number of opportunities to respond across four games

b the total number of opportunities to respond in the first four points of each of the four games

Table 32. MANOVA table for age level, expertise level, and age x expertise with the knowledge test, the serve test, and the groundstroke test as dependent variables.

Effect - Age Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	2.12
Pillai's Trace	3, 34	2.12
Wilk's Criterion	3, 34	2.12
Roy's Maximum Root	3, 34	2.12
Effect - Expertise Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	31.79**
Pillai's Trace	3, 34	31.79**
Wilk's Criterion	3, 34	31.79**
Roy's Maximum Root	3, 34	31.79**
Effect - Age x Expertise		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	.46
Pillai's Trace	3, 34	.46
Wilk's Criterion	3, 34	.46
Roy's Maximum Root	3, 34	.46

**p<.01

Table 33. Summary for the stepwise discriminant analysis with the knowledge test, the serve test, and groundstroke test used to predict expertise levels.

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Partial R2	F	Wilks' Criterion	Squared Canonical Correlation
1	Groundstroke		.62	60.95**	.38	.616
2	serve		.17	7.81**	.32	.683
3	Knowledge		.06	2.57	.30	.704

**p<.01

Means for the tests

	Novices	Experts
Groundstroke	47.4	65.7
Serve	12.25	28.15
Knowledge	8.55	19.7

Table 34. MANOVA table for age level, expertise level, and age x expertise levels using decision and execution as dependent variables for the serve.

Effect - Age Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 35	1.42
Pillai's Trace	3, 35	1.42
Wilk's Criterion	3, 35	1.42
Roy's Maximum Root	3, 35	1.42
Effect - Expertise Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 35	39.34**
Pillai's Trace	3, 35	39.34**
Wilk's Criterion	3, 35	39.34**
Roy's Maximum Root	3, 35	39.34**
Effect - Age x Expertise		
Statistic	df	F
Hotelling-Lawley Trace	3, 35	.76
Pillai's Trace	3, 35	.76
Wilk's Criterion	3, 35	.76
Roy's Maximum Root	3, 35	.76

**$p<.01$

Table 35. Summary for the stepwise discriminant analysis with decision and execution used to predict expertise levels.

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Partial R2	F	Wilks' Criterion	Squared Canonical Correlation
1	Decision		.63	65.82**	.36	.634
2	Execution		.11	4.38*	.33	.673

**p<.01

*p<.05

Means for decision and execution

	Novices	Experts
Decision	40.8	88.9
Execution	14.6	51.4

Table 36. MANOVA table for age level, expertise level, and age x expertise levels using decision and execution as dependent variable for game play following the serve.

Statistic	df	F
Effect - Age Level		
Hotelling-Lawley Trace	3, 34	5.16*
Pillai's Trace	3, 34	5.16*
Wilk's Criterion	3, 34	5.16*
Roy's Maximum Root	3, 34	5.16*
Effect - Expertise Level		
Hotelling-Lawley Trace	3, 34	26.53**
Pillai's Trace	3, 34	26.53**
Wilk's Criterion	3, 34	26.53**
Roy's Maximum Root	3, 34	26.53**
Effect - Age x Expertise		
Hotelling-Lawley Trace	3, 34	.04
Pillai's Trace	3, 34	.04
Wilk's Criterion	3, 34	.04
Roy's Maximum Root	3, 34	.04

**p<.01

*p<.05

Table 37. Summary for the stepwise discriminant analysis with decision and execution used to predict expertise levels.

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Partial R2	F	Wilks' Criterion	Squared Canonical Correlation
1	Decision		.68	83.74**	.31	.688

**p<.01

Means for control, decision, and execution

	Novices	Experts
Control	81.9	84.75
Decision	40.55	84.75
Execution	24.95	52.2

Table 38. Summary for the canonical correlation analysis using the knowledge test and the serve test to predict decision and execution components of performance for serve play.

Function	Cannonical Correlation	Eigan Value	F
1	.699	.956	7.6**
2	.183	.034	6.54

Multivariate Tests and F Approximations

Statistic	Value	df	F
Wilks' Lambda	.494	4, 72	7.60**
Pillai's Trace	.522	4, 74	6.53**
Hotelling-Lawley	.990	4, 70	8.66**
Roy's Greatest Root	.956	2, 37	17.69 upper bound

Table 39. Standardized canonical correlation coefficients for the canonical analysis using the knowledge test and the serve test to predict decision and execution components of performance for serve play.

Standardized Canonical Coefficents

	Function 1	Function 2
Knowledge	0.385	-1.038
Serve	0.772	0.793
Decision	0.958	-1.131
Execution	0.056	1.481

Table 40. Summary for the canonical correlation analysis using the knowledge test and the groundstroke test to predict control, decision, and execution components of performance for game play.

Function	Cannonical Correlation	Eigan Value	F
1	.794	1.710	7.58**
2	.063	.004	0.72

Multivariate Tests and F Approximations

Statistic	Value	df	F
Wilks' Lambda	.367	6, 70	7.58**
Pillai's Trace	.635	6, 72	5.58**
Hotelling-Lawley	1.714	6, 68	9.72**
Roy's Greatest Root	1.711	3, 36	20.53 upper bound

Table 41. Summary for the canonical correlation analysis using the knowledge test and the groundstroke test to predict control, decision, and execution components of performance for game play.

Standardized Canonical Coefficents

	Function 1	Function 2
Knowledge	0.416	1.189
Groundstroke	0.691	-1.053
Control	-0.004	0.176
Decision	0.650	-1.291
Execution	0.414	1.321

Table 42. Summary of regression analyses using the knowledge test and the serve test to predict each separate component of serve performance.

Squared Multiple correlations and F Tests

Dependet Variable	R2	Unbiased R2	F
Decision	.4604	.4881	17.63**
Execution	.2986	.2607	7.88**

Standardized Regression Coefficients

	Decision	Execution
Knowledge	0.2762	0.8307
Serve	0.5340	0.5056

Raw Regression Coefficients

	Decision	Execution
Intercept	3.5205	0.2605
Knowledge	0.5295	0.1345
Serve	1.5537	0.2429

Table 43. Summary of regression analyses using the knowledge test and the groundstroke test to predict each separate component of game play performance.

Squared Multiple correlations and F Tests

Dependet Variable	R2	Unbiased R2	F
Control	0.0452	-0.0064	0.88
Decision	0.5861	0.5637	26.20**
Execution	0.5178	0.4917	19.86**

Standardized Regression Coefficients

	Control	Decision	Execution
Knowledge	0.1312	0.2986	0.3310
Groundstroke	0.1054	0.5464	0.4686

Raw Regression Coefficients

	Control	Decision	Execution
Intercept	67.8867	5.7219	-4.6333
Knowledge	0.1888	0.4965	0.4277
Groundstroke	0.3372	2.0196	1.3464

Table 44. The mean percentage of successful responses for the serve and game play components of performance for age levels.

	10-11 Years (N=20)		12-13 Years (N=20)	
	M	S	M	S
Serve				
Decision	69.3	29.1	60.5	32.3
Execution	36.8	30.0	29.2	21.1
Game Play				
Control	82.2	24.1	84.5	22.4
Decision	63.5	25.1	61.2	28.6
Execution	32.6	18.9	44.6	21.1

Table 45. The mean percentage of successful responses for the serve and game play components of performance for expertise levels.

	Experts (N=20)		Novices (N=20)	
	M	S	M	S
Serve				
Decision	89.0	10.9	40.8	24.2
Execution	51.4	21.4	14.6	14.3
Game Play				
Control	84.8	29.2	81.9	15.1
Decision	84.1	14.6	40.5	15.5
Execution	52.2	13.4	25.0	17.0

Table 46. The mean percentage of successful responses for the serve and game play components of performance for age x expertise levels.

10-11 Years	Experts (N=10)		Novices (N=10)	
Serve	M	S	M	S
Decision	90.3	13.5	48.2	24.8
Execution	55.9	28.4	17.6	17.1
Game Play				
Control	83.4	30.2	81.0	17.6
Decision	84.6	8.8	42.4	16.1
Execution	45.5	14.9	19.7	12.8
12-13 Years	**Experts (N=10)**		**Novices (N=10)**	
Serve	M	S	M	S
Decision	87.6	8.1	33.3	22.3
Execution	46.9	11.4	11.5	10.8
Game Play				
Control	86.1	29.7	82.8	13.1
Decision	83.6	19.3	38.7	15.5
Execution	58.9	9.5	30.2	19.7

Appendix I

Additional Tables for Phase 2

Table 47. MANOVA table for age level, expertise level, and age x expertise with the total condition, action, and goal concepts in the situation interview as dependent variables.

Effect - Age Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	1.81
Pillai's Trace	3, 34	1.81
Wilk's Criterion	3, 34	1.81
Roy's Maximum Root	3, 34	1.81
Effect - Expertise Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	4.85**
Pillai's Trace	3, 34	4.85**
Wilk's Criterion	3, 34	4.85**
Roy's Maximum Root	3, 34	4.85**
Effect - Age x Expertise		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	.43
Pillai's Trace	3, 34	.43
Wilk's Criterion	3, 34	.43
Roy's Maximum Root	3, 34	.43

**p<.01

Table 48. Summary for the stepwise discriminant analysis with the total condition, action and goal concepts used to predict expertise levels for the situation interview.

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Partial R2	F	Wilks' Criterion	Squared Canonical Correlation
1	Total Conditions		.28	14.67**	.72	.279

**p<.01

Means for the concepts

	Novices	Experts
condition	3.70	7.70
Action	4.95	7.30
Goal	6.00	3.35

Table 49. MANOVA table for age level, expertise level, and age x expertise with the total number of different condition, action, and goal concepts in the situation interview as dependent variables.

Effect - Age Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	1.21
Pillai's Trace	3, 34	1.21
Wilk's Criterion	3, 34	1.21
Roy's Maximum Root	3, 34	1.21
Effect - Expertise Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	6.20**
Pillai's Trace	3, 34	6.20**
Wilk's Criterion	3, 34	6.20**
Roy's Maximum Root	3, 34	6.20**
Effect - Age x Expertise		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	1.12
Pillai's Trace	3, 34	1.12
Wilk's Criterion	3, 34	1.12
Roy's Maximum Root	3, 34	1.12

**p<.01

Table 50. Summary for the stepwise discriminant analysis with the total condition, action and goal concepts used to predict expertise levels for the situation interview.

_Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Partial R2	F	Wilks' Criterion	Squared Canonical Correlation
1	Different Actions		.31	17.02**	.69	.309

**p<.01

Means for the concepts

	Novices	Experts
condition	2.50	4.60
Action	2.75	4.20
Goal	2.80	2.30

Table 51. MANOVA table for age level, expertise level, and age x expertise with the total condition, action, and goal concepts in the point interview as dependent variables.

Effect - Age Level

Statistic	df	F
Hotelling-Lawley Trace	3, 34	.36
Pillai's Trace	3, 34	.36
Wilk's Criterion	3, 34	.36
Roy's Maximum Root	3, 34	.36

Effect - Expertise Level

Statistic	df	F
Hotelling-Lawley Trace	3, 34	2.03
Pillai's Trace	3, 34	2.03
Wilk's Criterion	3, 34	2.03
Roy's Maximum Root	3, 34	2.03

Effect - Age x Expertise

Statistic	df	F
Hotelling-Lawley Trace	3, 34	.36
Pillai's Trace	3, 34	.36
Wilk's Criterion	3, 34	.36
Roy's Maximum Root	3, 34	.36

Table 52. MANOVA table for age level, expertise level, and age x expertise with the total number of different condition, action, and goal concepts in the point interview as dependent variables.

Effect - Age Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	2.64
Pillai's Trace	3, 34	2.64
Wilk's Criterion	3, 34	2.64
Roy's Maximum Root	3, 34	2.64
Effect - Expertise Level		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	5.98**
Pillai's Trace	3, 34	5.98**
Wilk's Criterion	3, 34	5.98**
Roy's Maximum Root	3, 34	5.98**
Effect - Age x Expertise		
Statistic	df	F
Hotelling-Lawley Trace	3, 34	.28
Pillai's Trace	3, 34	.28
Wilk's Criterion	3, 34	.28
Roy's Maximum Root	3, 34	.28

**p<.01

Table 53. Summary for the stepwise discriminant analysis with the total condition, action and goal concepts used to predict expertise levels for the point interview.

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	Partial R2	F	Wilks' Criterion	Squared Canonical Correlation
1	Different Actions		.27	14.03**	.73	.270

**p<.01

Means for the concepts

	Novices	Experts
Condition	2.00	3.20
Action	0.95	2.60
Goal	1.40	1.95

Table 54. Means and standard deviations for total and different measures for the situation and point interviews by age levels.

	10-11 Years(N=20)		12-13 Years(N=20)	
	M	S	M	S
Situation Interview				
Total Concepts				
Condition	4.85	3.53	6.55	4.03
Action	6.15	2.56	6.10	3.18
Goal	3.45	1.57	5.90	10.58
Different Concepts				
Condition	3.10	2.13	4.00	2.18
Action	3.50	1.47	3.45	1.19
Goal	2.70	1.69	2.40	1.19

	10-11 Years(N=20)		12-13 Years(N=20)	
	M	S	M	S
Point Interview				
Total Concepts				
Condition	5.25	5.51	5.80	4.63
Action	2.45	3.00	3.35	3.25
Goal	3.15	2.43	3.65	3.34
Different Concepts				
Condition	2.05	1.54	3.15	1.98
Action	1.30	1.34	2.25	1.74
Goal	1.65	1.09	1.70	1.34

Table 55. Means, standard deviations, and the Kruskal-Wallace (chi-square approximation) test by age levels for the quality, connection, and linkage measures for the situation interview.

	10-11 Years(N=20)		12-13 Years(N=20)		
	M	S	M	S	2
Quality					
condition					
0	0.20	0.41	0.70	1.12	0.02
1	2.40	1.79	2.55	2.33	0.02
2	2.20	2.40	2.00	2.95	1.95
3	0.10	0.31	0.30	0.80	0
action					
0	0.70	1.59	0.05	0.22	3.27
1	3.10	2.07	1.30	1.89	0.63
2	2.10	1.74	1.50	1.76	0.76
3	0.50	1.05	0.40	0.99	0.27
Goal					
0	2.50	1.24	2.65	2.87	0.01
1	0.45	0.76	0.10	0.31	0.57
2	0.35	0.58	0.85	1.09	1.12
Linkages					
single	1.50	1.54	2.20	1.32	3.01
double	1.30	0.98	1.85	2.16	0.36
triple	0.55	0.83	2.20	1.32	0.30
Connections	0.20	0.41	7.85	4.87	0.02

Table 56. Means, standard deviations, and the Kruskal-Wallace (chi-square approximation) test by age levels for the quality, connection, and linkage measures for the point interview by age levels.

		10-11 Years(N=20)		12-13 Years(N=20)		
		M	S	M	S	2
Quality						
Condition	0	0.40	0.99	0.70	1.12	1.00
	1	2.70	2.94	2.55	2.33	0
	2	2.05	3.47	2.00	2.95	0.02
	3	0.05	0.22	0.30	0.80	1.19
Action	0	0	0	0.05	0.22	1.00
	1	1.30	2.05	1.30	1.89	0.01
	2	1.15	1.87	1.50	1.76	1.03
	3	0.15	0.37	0.40	0.99	0.28
Goal	0	2.20	1.77	2.65	2.87	0
	1	0.10	0.31	0.10	0.31	0
	2	0.80	1.32	0.85	1.09	3.22
Linkages						
single		6.35	3.65	7.60	4.45	0.58
double		0.75	1.65	0.65	0.93	0.15
triple		0.05	0.22	0	0	1.00
Connections		2.35	2.76	2.50	3.41	0.02

Table 57. Means, standard deviations, and the Kruskal-Wallace (chi-square approximation) test by age levels for agreements and disagreements for the point interview and game play performance components (decision and execution).

	10-11 Years(N=20)		12-13 Years(N=20)		
	M	S	M	S	2
Interview					
Agreements	0.85	1.08	2.20	2.84	1.45
Disagreements	0.80	1.51	1.30	2.13	0.54
Game Play					
Agreements	5.05	4.41	7.80	4.76	4.05*
Disagreements	6.50	6.10	5.40	4.39	0.12

Vita

Sue Lynn McPherson was born on September 26, 1954 in Gadsden, Alabama, but spent most of her childhood in Eatonton, Georgia. She attended Gatewood Schools and graduated as a member of the 1973 graduating class. Sue attended Auburn University for 2 years and completed her undergraduate degree in physical education at Georgia Southern College in Statesboro, Georgia in 1977.

From 1977 to 1978 she taught elementary physical education at the Georgia Southern Laboratory School and completed her M. Ed. in physical education. In August of 1978 she accepted a teaching position at Jeff Davis Middle School in Hazlehurst, Georgia. She served as a middle school physical education teacher and coached girls basketball at Jeff Davis High School.

In the fall of 1979, she entered the doctoral program at Louisiana State University. While completing the requirements for the doctoral degree, she was a teaching and research assistant in the School of HPERD. At the same time, Sue pursued a tennis professional career and received her USPTR, while managing a tennis club in Baton Rouge, Louisiana. She also ran her own tennis teaching business, "The Tourin Pro" and worked for the local YMCA as a fitness specialist. After completing the requirements for the Doctor of Philosophy Degree, Sue will serve as an assistant professor in physical education at Mars Hill College in North Carolina.

Sue is an avid sports person (jogging, fishing, golf), but her greatest pleasure in life comes from introducing a child or an adult to some type of physical activity that they might enjoy for the rest of their life.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Sue Lynn McPherson

Major Field: HPERD (Motor Development)

Title of Dissertation: The Development of Children's Expertise in Tennis: Knowledge Structure and Sport Performance

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

July 21, 1987